# TRANSACTIONS
OF THE
# AMERICAN FISHERIES SOCIETY


FIFTY-SEVENTH ANNUAL MEETING

HARTFORD, CONNECTICUT

AUGUST 8, 9, 10, 1927

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# American Fisheries Society

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**1927**

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# American Fisheries Society

ORGANIZED 1870 INCORPORATED 1910

## Officers for 1927-1928

| | |
|---|---|
| *President* | DR. EMMELINE MOORE, Albany, N. Y. |
| *Vice-President* | C. F. CULLER, LaCrosse, Wis. |
| *Secretary* | CARLOS AVERY, New York, N. Y. |
| *Treasurer* | T. E. B. POPE, Milwaukee, Wis. |
| *Librarian* | JOHN W. TITCOMB, Hartford, Conn. |

### Vice-Presidents of Divisions

| | |
|---|---|
| *Fish Culture* | JAMES A. LAIRD, Oakdale, N. Y. |
| *Aquatic Biology and Physics* | GEORGE C. EMBODY, Ithaca, N. Y. |
| *Commercial Fishing* | CHAS. R. POLLOCK, Seattle, Wash. |
| *Angling* | T. N. COTTRELL, Montgomery, Ala. |
| *Protection and Legislation* | LEE MILES, Little Rock, Ark. |

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| | |
|---|---|
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| E. LEE LECOMPTE, | Baltimore, Md. |
| W. E. ALBERT | Des Moines, Ia. |
| THADDEUS SURBER | St. Paul, Minn. |
| HONORE MERCIER | Quebec, Canada. |
| J. B. DOZE | Pratt, Kansas. |
| E. W. COBB | Farmington, Conn. |
| I. T. QUINN | Montgomery, Ala. |
| JOHN N. COBB | Seattle, Wash. |

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| | |
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| | |
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| D. H. MADSEN | Salt Lake City, Utah |
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| | |
|---|---|
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| DR. H. S. DAVIS | Washington, D. C. |

## PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

| | | | |
|---|---|---|---|
| 1. | William Clift | 1870-1872 | New York, N. Y. |
| 2. | William Clift | 1872-1873 | Albany, N. Y. |
| 3. | William Clift | 1873-1874 | New York, N. Y. |
| 4. | Robert B. Roosevelt | 1874-1875 | New York, N. Y. |
| 5. | Robert B. Roosevelt | 1875-1876 | New York, N. Y. |
| 6. | Robert B. Roosevelt | 1876-1877* | New York, N. Y. |
| 7. | Robert B. Roosevelt | 1877-1878 | New York, N. Y. |
| 8. | Robert B. Roosevelt | 1878-1879 | New York, N. Y. |
| 9. | Robert B. Roosevelt | 1879-1880 | New York, N. Y. |
| 10. | Robert B. Roosevelt | 1880-1881 | New York, N. Y. |
| 11. | Robert B. Roosevelt | 1881-1882 | New York, N. Y. |
| 12. | George Shepard Page | 1882-1883 | New York, N. Y. |
| 13. | James Benkard | 1883-1884 | New York, N. Y. |
| 14. | Theodore Lyman | 1884-1885 | Washington, D. C. |
| 15. | Marshall McDonald | 1885-1886 | Washington, D. C. |
| 16. | W. M. Hudson | 1886-1887 | Chicago, Ill. |
| 17. | William L. May | 1887-1888 | Washington, D. C. |
| 18. | John Bissell | 1888-1889 | Detroit, Mich. |
| 19. | Eugene G. Blackford | 1889-1890 | Philadelphia, Pa. |
| 20. | Eugene G. Blackford | 1890-1891 | Put-in Bay, Ohio. |
| 21. | James A. Henshall | 1891-1892 | Washington, D. C. |
| 22. | Herschel Whitaker | 1892-1893 | New York, N. Y. |
| 23. | Henry C. Ford | 1893-1894 | Chicago, Ill. |
| 24. | William L. May | 1894-1895 | Philadelphia, Pa. |
| 25. | L. D. Huntington | 1895-1896 | New York, N. Y. |
| 26. | Herschel Whitaker | 1896-1897 | New York, N. Y. |
| 27. | William L. May | 1897-1898 | Detroit, Mich. |
| 28. | George F. Peabody | 1898-1899 | Omaha, Nebr. |
| 29. | John W. Titcomb | 1899-1900 | Niagara Falls, N. Y. |
| 30. | F. B. Dickerson | 1900-1901 | Woods Hole, Mass. |
| 31. | E. E. Bryant | 1901-1902 | Milwaukee, Wis. |
| 32. | George M. Bowers | 1902-1903 | Put-in Bay, Ohio. |
| 33. | Frank N. Clark | 1903-1904 | Woods Hole, Mass. |
| 34. | Henry T. Root | 1904-1905 | Atlantic City, N. J. |
| 35. | C. D. Joslyn | 1905-1906 | White Sulphur Springs, W. Va. |
| 36. | E. A. Birge | 1906-1907 | Grand Rapids, Mich. |
| 37. | Hugh M. Smith | 1907-1908 | Erie, Pa. |
| 38. | Tarleton H. Bean | 1908-1909 | Washington, D. C. |
| 39. | Seymour Bower | 1909-1910 | Toledo, Ohio |
| 40. | William E. Meehan | 1910-1911 | New York, N. Y. |
| 41. | S. F. Fullerton | 1911-1912 | St. Louis, Mo. |
| 42. | Charles H. Townsend | 1912-1913 | Denver, Colo. |
| 43. | Henry B. Ward | 1913-1914 | Boston, Mass. |
| 44. | Daniel B. Fearing | 1914-1915 | Washington, D. C. |
| 45. | Jacob Reighard | 1915-1916 | San Francisco, Calif. |
| 46. | George W. Field | 1916-1917 | New Orleans. La. |
| 47. | Henry O'Malley | 1917-1918 | St. Paul, Minn. |
| 48. | M. L. Alexander | 1918-1919 | New York, N. Y. |

| | | | |
|---|---|---|---|
| 49. | Carlos Avery | 1919-1920 | Louisville, Ky. |
| 50. | Nathan R. Buller | 1920-1921 | Ottawa, Canada. |
| 51. | William E. Barber | 1921-1922 | Allentown, Pa. |
| 52. | Glen C. Leach | 1922-1923 | Madison, Wisconsin. |
| 53. | George C. Embody | 1923-1924 | St. Louis, Mo. |
| 54. | Eben W. Cobb | 1924-1925 | Quebec, Canada. |
| 55. | Charles O. Hayford | 1925-1926 | Denver, Colorado. |
| 56. | John W. Titcomb | 1926-1927 | Mobile, Alabama. |
| 57. | Dr. Emmeline Moore | 1927-1928 | Hartford, Conn. |

*A special meeting was held at the Centennial Grounds, Philadelphia, Pennsylvania, October 6 and 7, 1876.

## TABLE OF CONTENTS

## Appendix

# PART I
# BUSINESS SESSIONS

# PROCEEDINGS

## of the

## American Fisheries Society

## FIFTY-SEVENTH ANNUAL MEETING

## at

## HARTFORD, CONNECTICUT

### August 8, 9, 10, 1927

The Fifty-seventh annual meeting of the American Fisheries Society convened at the Hotel Bond, Hartford, Conn., on Monday, August 8, 1927, at 10 a. m., President John W. Titcomb presiding.

### REGISTERED ATTENDANCE

JOHN W. TITCOMB, Superintendent Conn. State Board of Fisheries and Game, Hartford, Conn.

CARLOS AVERY, Secretary American Fisheries Society, New York

JAMES A. LAIRD, South Side Sportsman's Club, Oakdale, N. Y.

SAMUEL I. BORGER, Fish Culturist, Brookhaven, N. Y.

CHESTER A. PITNEY, Peppinridge Lake Trout Hatchery, Eastport, L. I.

C. P. PETERSON, Game and Fish Commissioner, Bisbee, North Dakota.

MAYNARD S. JOHNSON, Division of Economic Zoology, U. of Minnesota, St. Paul, Minn.

JOHN N. COBB, College of Fisheries, University of Washington, Seattle, Wash.

PERCY VIOSCA, JR., Director of Fisheries, Department of Conservation of Louisiana, New Orleans, La.

JOHN R. GREELEY, Ichthyologist, New York State Conservation Department, Survey 1927, Ithaca, N. Y.

CARL L. HUBBS, Museum of Zoology, Ann Arbor, Mich.

EMMELINE MOORE, Investigator in Fish Culture, Albany, N. Y.

EBEN W. COBB, Field Supervisor, Hartford, Conn.

WM. H. ROWE, Trout Breeder, West Buxton, Me.

FRANK W. WARDWILL, Maine Fish and Game Association, Portland, Me.

J. F. HAMPTON, Linville, N. C.

ALBERT M. POWELL, Lewistown, Md.

CHAS. O. HAYFORD, Superintendent State Hatchery, Hackettstown, N. J.

NATHAN R. BULLER, Commissioner of Fisheries, Harrisburg, Pa.

GEO. F. STACK, Superintendent Paradise Brook Trout Co., Cresco, Pa.

L. H. SPRAGLE, Treasurer, Paradise Brook Trout Co., Cresco, Pa.

E. LEE LECOMPTE, State Game Warden, Baltimore, Md.
H. D. MCHOLLAND, Chamber of Commerce, San Francisco, Cal.
T. SURBER, Superintendent of Propagation, St. Paul, Minn.
KARL C. KULLE, Fish and Game Commissioner, Suffield, Conn.
WM. F. MONROE, Superintendent State Fish Hatchery, Palmer, Mass.
OTIS D. MONROE, President Willow Brook Hatchery, Westfield, Mass.
CHAS. E. WHEELER, Fish and Game Commissioner, Stratford, Conn.
G. W. FIELD, Massachusetts Fish and Game Association, 3 Joy St., Boston, Mass.
N. BORODIN, Museum of Natural History, New York City.
WILLIAM C. ADAMS, Director of Fisheries and Game, Department of Conservation, Boston, Mass.
LEE MILES, Game and Fish Commissioner, Little Rock, Ark.
HARRY NEELLY, Game and Fish Commissioner, Little Rock, Ark.
GUY AMSLER, Secretary Game and Fish Commission, Little Rock, Ark.
DAVID L. BELDING, Hingham, Mass.
L. B. HANDY, Wareham, Mass.
H. S. DAVIS, U. S. Bureau of Fisheries, Washington, D. C.
E. C. YOUNG, Official Reporter, 36 Melgund Ave., Ottawa, Ont.
A. H. DINSMORE, Superintendent U. S. Fisheries Station, St. Johnsbury, Vt.
RUSSELL F. LORD, Pittsford, Vt.
CHAS. K. STILLMAN, M. D., Mystic, Conn.
JAMES D. DEROCHER, Superintendent U. S. Fisheries Station, Nashua, N. H.
R. V. BANGHAM, Investigator Fish Diseases, Ohio Fish and Game Division, Wooster, Ohio.
G. C. EMBODY, Cornell University, Ithaca, N. Y.
MRS. BESSIE ANDERSON, Secretary Board Game and Fisheries, Atlanta, Georgia.
KENNETH E. COBB, Fish Culturist, Farmington, Conn.
J. B. DOZE, State Fish and Game Warden, Pratt, Kan.
F. C. WALCOTT, President State Board of Fisheries and Game, Norfolk, Conn.
LEWIS RADCLIFFE, U. S. Bureau of Fisheries, Washington, D. C.
J. P. SNYDER, Superintendent Fisheries Station, Cape Vincent, N. Y.
FRANK MILLER, Fish Culturist, De Bruce, N. Y.
IDA MELLEN, Aquarist, The Aquarium, New York City.
I. T. QUINN, Commissioner of Game and Fisheries, Montgomery, Ala.
C. J. MEREDITH, Superintendent of Wardens, Frankfort, Ky.
GEO. C. WAGGONER, Executive Agent, Frankfort, Ky.
LOUIS HORST, Superintendent of Hatchery, Amherst, Mass.
TED COTTRELL, Chief Game Warden, Birmingham, Ala.
R. S. W. BROWNE, Birmingham, Ala.
MISS AMY H. MARVIN, New Preston, Conn.

MISS MAUD C. BOLLES, Bridgeport, Conn.
HENRY W. BEEMAN, Waramaug Bass Hatchery, New Preston, Conn.
CLYDE B. TERRELL, Aquatic Farmer, Oshkosh, Wis.
RALPH R. BITZER, Superintendent State Hatchery, Montague, Mass.
V. K. IRION, Commissioner of Conservation, Louisiana.
MRS. L. R. RUSSELL, Secretary to Commissioner of Conservation, La.

President Titcomb welcomed the members to Hartford and announced that all formalities would be dispensed with and that the convention would proceed at once to the business of the session.

## REPORT OF THE SECRETARY

*To the Officers and Members of the American Fisheries Society:*

In addition to the applications now on file for acceptance at this meeting, 99 new members have been admitted to the Society since my last report, 70 of these since the last annual meeting. Four of the 70 have been life members, 3 state members, 7 clubs or dealers and 56 active members.

All of the life members secured, 4 of the dealers and 18 of the active members or a total of 26 new members have been secured through the instrumentality of James A. Laird of Oakdale, L. I. In securing this splendid list of new members for the Society, Mr. Laird has placed it under great obligation and I trust that some suitable recognition can be made of his loyal and splendid service in the interest of the Society. Several other members are entitled to commendation for turning in a number of new members among whom Charles R. Pollock of Seattle, Washington, has recommended 6, Captain C. F. Culler of LaCrosse, Wis., 6, President John W. Titcomb 4, ex-President Charles O. Hayford 5 and others in less numbers.

The Treasurer has certified that 39 members have been dropped from the roll for non-payment of dues and 5 members have died, leaving a net gain since the last annual meeting of 26 members.

The Secretary has been able to secure a few new members from names furnished him by members of the Society but he could accomplish a great deal more if he had more cooperation from the members in furnishing names of prospects.

A marked increase in the correspondence of the Secretary's office has indicated added interest in the work of the Society. Upwards of 1,000 letters have been written by the Secretary during the past year, nearly all in answer to correspondence, much of which correspondence

has consisted of requests for information on methods of propagation of various species of fish.

At the suggestion of the President, members were invited in the circular of May 16th to make subscriptions of $5.00 each to create a sum to cover the cost of the preparation and publication of a catalogue or index of the transactions of the Society. This is an old subject but the need of such a catalogue is now almost imperative and it is hoped that this present session will not adjourn without making some definite provision for such a publication. There is no question but what it would greatly increase the value of the Society's Library, increase public interest in its work and result in increased membership.

Our constitution and by-laws provide that the President of the United States, the Governors of the several states and the Secretary of Commerce of the United States shall be honorary members of the Society and in addition to that, any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular meeting. There are on the records of the Society at present 14 honorary members and 12 corresponding members. It is suggested that a committee be created at this meeting to canvass the list of honorary and corresponding members appearing upon our records and to make suitable recommendation to the Society for any changes that should in its opinion be made. It is apparent that these lists should be revised from time to time.

The policy inaugurated several years ago of supplying the printed Transactions only to members who are paid in advance, has been followed during the past year and the results prove that it should be the permanent policy of the Society. The furnishing of printed Transactions to honorary and corresponding members is a question which should be definitely determined for the guidance of the Secretary.

In view of the improved financial condition of the Society, it is suggested that resumption of the awarding of prizes might stimulate original research and the preparation of valuable papers.

It is not incumbent upon the Secretary to report on the finances of the Society as the collection of dues and the financial records are in the hands of the Treasurer and his report is at hand. I wish to take this opportunity, however, to cite the very painstaking and efficient work of the Treasurer, Mr. Pope, who has safeguarded the interests of the Society in every possible manner, as a result of which the finances are probably in better shape than they have been for many years.

Respectfully submitted,

CARLOS AVERY, *Secretary.*

The report of the secretary was, on motion, accepted and placed on file. John N. Cobb was named as Treasurer pro tem.

## REPORT OF THE TREASURER

*To the American Fisheries Society:*

Herewith is submitted the annual report of the Treasurer covering the period from the last annual meeting held at Mobile, Alabama, on September 22, 1926 to June 30, 1927, inclusive.

It is indeed a pleasure to report the details of the finances of the Society for the past year. Last September, at the Mobile meeting, we reported the complete liquidation of all of our indebtedness to the Permanent Fund, the payment of all of our outside bills, and a small cash-balance on hand. The period covered by this report therefore has been more or less of an experimental year, it being our first year clear of all debts of any kind for many years, and one during which we had to determine whether we could operate successfully within our revenue consisting only of membership dues and the sale of such publications as we could effect. This past year we have received no donations and yet have not only paid all of our obligations out of the General Fund and have a cash-balance on hand but have been able to transfer all money received from life-memberships ($250) to the credit of the Permanent Fund for the first time in the history of the society. The Permanent Fund shows no withdrawals except for investment and brokerage thereof. Our total assets, comprising securities, cash on hand in the General Fund and bank balance of the Permanent Fund, amount to over $4,000 all clear. A review of all preceding financial reports shows the society to be in the most prosperous and favorable condition that it has ever been. The causes that have led to this excellent financial state may, I believe, be outlined as follows: (1) Restricting the cost of the Transactions to a fairly satisfactory but inexpensive edition; (2) Mailing of the Transactions to only those members who have actually paid for the same; (3) Reducing the expenses of administrative officers to the actual cost of operations, without salaries, and with a knowledge of the society's finances as announced by the Treasurer from time to time; (4) Receipt of a goodly number of new members with the revenue derived therefrom; (5) Systematically reminding the members to pay their dues.

In his preceding report the treasurer recommended the transfer of such few active members as had paid their dues for 25 consecutive years and who found themselves unable to make further payments to the life-membership list. Only one member was so transferred. The results of this policy to date can hardly be termed detrimental to our financial condition but, on the contrary, is as it should be, a means whereby we can retain on our list those loyal members who have given us so much in the past but are unable now to continue financially.

The number of members annually dropped for non-payment of dues is still greater than is to be desired but no greater perhaps in propor-

tion to our total membership than of other scientific societies. Fortunately, so far, the number of new members has exceeded the loss through delinquency, death and resignation. In this respect the Society can safely reward members that bring in six or more new members by an exemption of dues for a year.

Your attention may now be invited to the following items:

## GENERAL FUND

### *Receipts*

| | | |
|---|---|---|
| Balance on hand at meeting of 1926 | | $38.75 |
| Annual Dues | | |
| Individuals and Libraries | | |
| For the year 1923 | $3.00 | |
| For the year 1924 | 24.00 | |
| For the year 1925 | 69.00 | |
| For the year 1926 | 1,253.61 | |
| For the year 1927 | 27.00 | |
| Clubs and Dealers | | |
| For the year 1926 | 140.00 | |
| State Memberships | | |
| For the year 1926 | 170.00 | |
| Life Memberships | 250.00 | |
| Sale of Publications | 116.58 | |
| | | 2,053.19 |
| Total Receipts | | $2,091.94 |

### *Disbursements*

| | | |
|---|---|---|
| Transactions, 1926, Vol. 56, | | |
| Printing of (800 copies) | $560.00 | |
| Colored plates for (800) | 88.00 | |
| Mailing jackets for | 18.00 | |
| Postage for mailing of, | 47.62 | 713.62 |
| 1926 Meeting at Mobile, Alabama, | | |
| Reporting proceedings of | 280.00 | |
| Printing programs for | 15.00 | 295.00 |
| Expenses of Secretary's Office, | | |
| Postage, telegrams and assistance for year 1925 | 132.39 | |
| Clerical assistance for 1925 | 37.50 | |
| Postage, printing of envelopes, stationery and circulars | 119.21 | |
| Loose-leaf Record System | 11.55 | |
| Clerical assistance for 1926 | 75.00 | 375.65 |
| Expenses of President & Librarian, | | |
| Postage | 15.00 | |
| Clerical assistance for 1926 | 50.00 | 65.00 |
| Expenses of Treasurer's Office, | | |
| Clerical assistance for 1925 | 50.00 | |
| Postage, printing of billheads and envelopes | 61.50 | |
| Clerical assistance for 1926 | 75.00 | |
| Bond Premium | 2.50 | 189.00 |

| | | | |
|---|---|---|---|
| Membership in National Conference on Outdoor Recreation, 1926 ........ | 10.00 | 10.00 | |
| Transfered to Permanent Fund on account of 5 Life-memberships ..... | 250.00 | 250.00 | |
| | | | $1,898.27 |
| Balance on hand .......................... | | | $ 193.67 |

## PERMANENT FUND

*Receipts*

| | | |
|---|---|---|
| Balance on hand at meeting of 1926 .................................... | | $3,230.31 |
| Bank Interest to June 1, 1927 .......................... | $52.61 | |
| Dividend on stock to July 1, 1927 .................... | 120.00 | |
| By transfer from General Fund on account of 5 Life-memberships ..................... | 250.00 | |
| | | 422.61 |
| Total Receipts ............................................ | | $3,652.92 |

*Disbursements*

| | | |
|---|---|---|
| Purchase of 40 shares Consolidated Railroads of Cuba, 6% Preferred stock at 70¼ .............. | $2,810.00 | |
| Brokerage fee on above ..................................... | 7.00 | |
| | | 2,817.00 |
| Balance on hand ........................................... | | $ 835.92 |

As shown above the Society has received $120 dividend on its holdings for the first six months of investment which is twice the amount of interest received for a similar period from a National bank. The cash-balance of the Permanent Fund is deposited in the National Bank of Commerce of Milwaukee.

Respectfully submitted,

T. E. B. Pope, *Treasurer.*

The report was received and referred to the Auditing Committee.

## REPORT OF THE LIBRARIAN

MR. TITCOMB: I have covered this subject rather fully in the last two meetings. We have a very large number of Transactions on hand, properly stored and available. We can always get them out quite easily for mailing. We sold a few of the back numbers this last year, but not as many as we ought to. I think the members are coming to realize more and more the value of these publications. We are having further demands for them also from the libraries. The catalogue which Mr. Avery referred to would make these publications far more valuable, especially when one is contemplating the preparation of a paper. Many of the subjects we discuss have been discussed along the same lines in years gone by, and those who are dealing with particular subjects could refresh themselves on what has gone before if they only had an index. The circular which was sent out to the libraries and to members met with very little response, much to my surprise. I would give a good deal more than five dollars for a copy of that catalogue; it would likely cost us more than five dollars to publish it. I hope you will all keep in mind that we have these publications of the past and that you can obtain them for yourselves; or you might run across people who would be interested in them. We want to create a demand among the libraries and that can be accomplished by going to the library and asking for publications of the Fisheries Society for certain years. This is the only society of its kind in the country, and its publications should be available in all important libraries. I get a great many letters from people who want to know about certain subjects which are treated in these publications; they go to the libraries, but very rarely get what they want.

## APPOINTMENT OF COMMITTEES

*Committee on Nominations:* Nathan R. Buller, Chairman; Guy Amsler, I. T. Quinn, Eben W. Cobb, L. H. Spragle.

*Committee on Time and Place:* Charles O. Hayford, Chairman; John N. Cobb, William C. Adams, Thaddeus Surber, Percy Viosca, Jr.

*Auditing Committee:* James A. Laird, Chairman; C. P. Peterson, Geo. C. Waggoner.

*Finance Committee:* F. C. Walcott, Chairman; Carlos Avery.

*Committee on Resolutions:* Lee Miles, Chairman; Lewis Radcliffe, Seth Gordon.

*Committee on Memorials:* Ward T. Bower, Chairman; T. E. B. Pope, Carlos Avery.

*Committee on Program*: A. H. Dinsmore, Eben W. Cobb.

Lewis Radcliffe was designated as the representative of the Society to attend the meeting of the U. S. Fisheries Association at Boston, Mass., Aug. 12 and 13, 1927.

# REPORTS OF VICE PRESIDENTS OF DIVISIONS

## REPORT OF THE DIVISION OF COMMERCIAL FISHERIES

By Lewis Radcliffe.

## STATISTICS—THE BASIS FOR LEGISLATIVE ACTION

With the awakening of the public conscience to the necessity for conserving our fisheries, numberless bills are being introduced into our state legislatures which are intended to cure ills which may or may not exist. Most of these are based on personal opinion. In only a few instances is there adequate knowledge of the fundamental facts necessary to draft intelligent legislation. Anglers may align themselves against the commercial fishermen and both may make things uncomfortable for the state authorities and for different reasons. The state legislative committees listen to a mass of conflicting opinions and may refuse to make any changes in the laws or may follow the lead of the side exerting the greatest pressure without definite knowledge as to whether the law is warranted; or wholly unjustifiable.

Granting that these conditions exist, we are confronted with the task of determining what facts are needed to serve as a basis for legislative action and the means of securing such information. First, the facts must reveal for a period of time the condition of the fishery, i. e., the relative abundance of the particular species. This will show whether the existing supply is sufficient to meet the strain of the fishery or whether the capital stock is being depleted endangering the future of the fishery. In the second place we must have some knowledge of the natural changes in abundance which occur without regard to the effects of the fishery itself upon the supply. These are the fundamentals upon which we must base our regulatory control over the fisheries.

We cannot estimate the number of shad or mackerel in the sea with the same facility that we can approximate the amount of lumber in a forest. It is possible to ascertain the commercial catch of each important species of fish, the amount of gear used, and the number of fishing days employed. By collecting and analyzing such data properly we can arrive at justifiable opinions regarding the condition of the fishery and the need for further restrictions on the commercial catch or the possibilities of increasing the catch with safety to the supply. The first requisite is the taking of an accurate record of the catch, of the units of gear used, and the number of days or trips devoted to fishing.

Statistics of a fishery unless taken regularly over a period of years have little value for this purpose. The statistics should be collected regularly and they should be uniform so that state figures may be combined to provide for the tabulation of each species throughout its entire range. It is believed that each state should make the collection of fish-

ery statistics a requirement of law and that some central agency such as the Bureau of Fisheries should tabulate the data by states and by species and analyze the data as necessary to determine the condition and trend of each fishery. By this process we will acquire the facts necessary to serve as a basis for proper legislative action and thereby eliminate much guess-work connected with fisheries legislation.

The statistical section of the Scientific Division Committee of the U. S. Fisheries Association has drafted a bill which has been modified in conference with members of the staff of the U. S. Bureau of Fisheries to meet the requirements of the biologist as fully as practicable. The Southern Fisheries Association has approved of this bill and recommended its adoption by the states. It is expected that the U. S. Fisheries Association will also approve of its adoption. I am attaching a copy of this bill and heartily recommend that the American Fisheries Society express its approval of the bill and urge its adoption by the states. I also recommend that members of this society use their individual efforts to secure the passage of such legislation in their respective states.

## Proposed Bill For The Collection, Compilation And Dissemination Of Fishery Statistics.

Section 1. Every person, firm, or corporation, whose residence, (and or) principal place of business is located within the State of ———— who engages in the business of catching, taking, raising, or producing for sale, fish, shellfish, including mollusks, crustaceans and other aquatic products, shall first be licensed by the ————(Board or Commission.) The fee for such license shall be $———— (Nominal) for the calendar year or any fraction thereof.

Section 2. Every person, firm, or corporation licensed under Section 1 of this Act shall make a legible report to the ———— (Board or Commission), on forms furnished by the said ———— (Board or Commission) of the quantities and values of each variety of fish, shellfish, and other aquatic products caught, taken, raised, or produced, the area or location of the fishery, and the type and amount of gear or apparatus employed.

Section 3. Every person, firm, or corporation licensed under Section 1 of this act shall make the reports, required in Section 2 of this Act, on or before the tenth day of each month, covering the preceding month, provided that when vessels are at sea said reports shall be sent to the said ———— (Board or Commission) within ten days after arrival at port.

Section 4. Every person, firm, or corporation licensed under Section 1 of this Act shall, on or before the fifteenth day of February, make a legible report to the ———— (Board or Commission) covering the preceding year, of the type, size, and value of each vessel and boat owned or operated by him or them; the number, type, size, and value of each kind of fishing gear or apparatus used in connection with fish production; and the number of persons employed.

Section 5. It shall be the duty of the ———— (Board or Commission) to prepare suitable report forms, distribute them to the licensees, insure the collection of said reports and compile the data in such form as is necessary to show the condition and trend of the fisheries. It shall also be the duty of the ———— (Board or Commission) to preserve the individual reports on file in proper form for further studies as may be needed by state or Federal authorities, for study of fishery problems. It shall also be the duty of the ———— (Board or Commission) to prepare for public release a statement showing the quantity and value of each variety of fish, shellfish, or other aquatic product taken during the preceding month and to provide such licensee with a copy of said statement.

Section 6 and Section 7. It shall be unlawful for the ———— (Board or Commission) or any of its employees or agents to reveal any information secured under this Act whereby the data furnished by any particular person, firm, or corporation, can be identified except as provided by law. Any person, firm, or corporation failing to comply with the provisions of this Act shall be guilty of a misdemeanor and punishable by a fine of not more than ———— dollars or revocation of his license or both. Upon a third conviction revocation of license shall be mandatory.

Section 8. This Act shall become effective on January 1 next succeeding the passage of this Act. All other acts in conflict are hereby expressly repealed.

PRESIDENT TITCOMB: This is rather a dry subject—a matter of statistics—nevertheless it is very important. The Bureau of Statistics has never taken statistics in any one section more than once in several years, and it is interesting to note that the United States Fisheries Association, with its branches along the coast, has passed a resolution endorsing this proposed bill by the various states so that they will have uniform legislation. We are fortunate in having a man here who went to Washington and got some instruction on taking statistics; he has taken statistics during the past two years and has done it very well indeed. We have not got state legislation in this matter. I think, however, that it can be put through in time, when the legislature realizes the importance of it.

MR. E. LEE LECOMPTE (Maryland): I may say that our state is similar to Connecticut in regard to the law to which this bill refers. I feel that it is a very big step forward to have these statistics. It is impossible for the Bureau of Fisheries to secure them in the states. Through Mr. Earle's energetic efforts, the last session of the general assembly of Maryland provided for the appointment of an advisory board, and an auditor, whose duty shall be to call on the commercial fishermen covering all phases of the commercial fishing indus-

try and check up on their receipts and disbursements, their shipments out, whether in the state or out of it, and so forth. At the last session of our general assembly Mr. Earle received very favorable comment on his report, especially with regard to the number of bushels of oysters taken in the state, and there was no possible way of backing up his statement, except of course, on the Bureau of Fisheries statistics—the best they could get. Previously our only statistics were obtained by checking up with the express companies, but in future we shall be able to get them on a more definite basis.

MR. JOHN N. COBB: In the State of Washington they formerly taxed all commercial products landed, but unfortunately for statistical purposes, they included only what was taxed. In other words, the state fisheries, according to the State Fish Commissioner, comprised only whatever the fishermen had paid taxes on; if they did not have to pay a tax, the products were not recognized at all. But the State Legislature in its wisdom has since seen fit to tax everything, so that every person who lands a product has to pay a certain tax per pound, and the whole industry is regulated on the basis of those taxes, as well as some additional license fees. In other words, we are applying to the commercial fisheries exactly the same plan that has been applied to the game fisheries for many years, that of making the industry support itself. That will work, of course, with the commercial states so far as fisheries are concerned, but I doubt whether it would work anywhere else.

PRESIDENT TITCOMB: Does that apply to outside fisheries beyond your jurisdiction?

MR. JOHN N. COBB: We count everything that is landed by a Washington boat. Of course a good deal of it is landed in Alaska and shipped down; we cannot count that. An effort is being made, however, to devise a scheme by which they will assess that as well as the rest, and I think the effort will be successful. Of course the states are very anxious to get the money, and usually in such cases the legislature can find some way of applying the necessary regulation.

## REPORT OF VICE PRESIDENT, DIVISION OF AQUATIC BIOLOGY AND PHYSICS.

BY DR. H. S. DAVIS.

MR. PRESIDENT: In presenting a report to the society from this division, I feel I can do no better than to emphasize the importance of the application of scientific principles to fish culture. Of course this is being done to a greater or less extent, for in truth no fish culture would be possible without the practical application of biological laws, but I believe I am safe in saying that in none of our fish cultural practices has full advantage been taken of the available fund of biological knowledge having a direct bearing on the problem. Too often the methods adopted have been empirical and of doubtful efficiency. In some instances there has even been a tendency to disparage the value of scientific knowledge and to intimate that the technical aspects of aquatic biology have little bearing on practical fish culture. While such an attitude on the part of some fish culturists is very unfortunate I feel that the biologists are not entirely blameless. In not a few instances their researches have been publishd in such technical form that they could be appreciated only by specialists, and no attempt has been made to point out their application to practical fish culture.

I believe all progressive fish culturists will agree with me that the only way in which fish culture—or better, aquiculture—can advance is by utilizing to the full our knowledge of aquatic biology and where that knowledge is deficient, as is too often the case, by encouraging further investigations to fill in the gaps. This is especially true in the case of pond culture where success is dependent on the proper utilization of a series of complicated physical, chemical and biological agencies. Every pond is a microcosm, a little world in itself, in which there is a fascinating series of changes going on throughout the year. It is up to the fish culturist to take stock of these natural processes and adapt them and mold them to his ends. Just so far as he is successful in doing this, just so far is he a successful fish culturist and no farther.

Aquiculture is now following close on the footsteps of its sister science, agriculture. Just as the farmer has learned that he must have some knowledge of the essentials of soil physics, soil chemistry, and soil biology, if he is to be successful so the fish culturist must have at least a general knowledge of the various factors which influence the fish life in his ponds. He must know the most favorable conditions for the development and growth of each species of fish with which he has to deal. He must know the proper food for his fish at different ages and the best methods of producing it. He must know the parasites and diseases which affect each species of fish and the most effective methods of controlling them. These are only a few of a large number of complicated and in-

teracting factors of which the fish culturist must have some knowledge if he is to succeed. True, he may get by for a year or two, or even longer, with little knowledge of the fundamental facts, just as the novice may make a killing in his first poker game, but such luck can not last indefinitely and in the long run it is the man with a thorough knowledge of the factors involved, and the grit and the energy to see that his hatchery is conducted so as to take full advantage of our knowledge of aquicultural principles, who will be the successful fish culturist of the future.

Please do not misunderstand me. I am not proposing that our hatchery superintendents should be specialists in aquatic biology. Far from it! Too often such men are scientists first and fish culturists afterwards instead of the reverse as should be the case, but I do believe that every hatchery superintendent. and every fish culturist should have a thorough knowledge of the fundamental principles involved in aquiculture, so far as we know them. Then it will not be necessary to run our hatcheries on an empirical basis and if things this year do not work out as they did last year the fish culturist will be able, in many instances at least, to determine the cause and to govern himself accordingly.

Personally, I have no patience with the fish culturist who is content to let well enough alone and to go on year by year in the same old way just so as he is able to get by. As in other fields of endeavor we can not stand still. If we do not progress we must, perforce, slip backwards. Aquiculture is a growing science, many of our present methods are crude and inefficient, even though they represent the best we can do with our limited knowledge. But to me it is this that makes aquiculture so interesting and fascinating and I glory in the fact that everything is not cut and dried, that it is still a young and comparatively undeveloped science, and that each and every one of us, if we will, can contribute to its advancement.

Finally, I want to emphasize the fact that the outlook is most encouraging. The increasing attendance at the meetings of the Society where the principles and methods of aquiculture can be discussed to our mutual benefit is abundant proof that American fish culturists are not satisfied to rest on the achievements of the past. Furthermore, there is an increasing tendency on the part of the State Commissions to employ specialists who are at the service of their fish culturists whenever occasion demands. We may, therefore, face the future with confidence, secure in the knowledge that the development of improved and more efficient methods of utilizing our aquatic resources will enable us to meet the constantly increasing demands for more and better fish.

## REPORT OF THE VICE PRESIDENT OF THE DIVISION OF ANGLING.

MR. WILLIAM C. ADAMS (Massachusetts): Mr. President. I suppose all of us are so sated with the pleasures of the past fishing season that it is not necessary for me to enlarge on either the joys or the philosophy of angling. But if any of you have failed this year to get the kinks out of your wrist; if you have not experienced the thrill of observing the coming of spring as first announced by the skunk cabbage pushing up through the black soil, and later the appearance of the lacey filament of the white birch on the hillside, I can only say that unfortunately you have postponed a rare pleasure which it will be impossible for you to go back and reclaim.

This angling business is an aspect that we have not sufficiently emphasized. Every year we convene and we talk about trout and about small-mouthed bass. The time has come when we should appreciate the fact that the rank and file of the anglers go out to catch a mess of fish and are not particularly interested in the species. So long as they can surround enough fish to grease a pan and give them a toothsome morsel, they are satisfied. Therefore I think we should consider more often and more at length at these meetings some methods by which we can replace in increasing number our common pond fish. I refer particularly to such species as pickerel, the hornpout, white and yellow perch, the crappie and the bluegill and other pond fish which your simon pure angler looks on more or less with scorn.

We can collect the spawn of the yellow perch and hatch them world without end, but after you get them, what are you going to do with them? We can grow the bluegill in tremendous numbers by following certain lines. We must employ pond cultural methods on an increasing scale. We must establish series of ponds located at proper geographical points in our states where we have the absolute control over the water, where we can drain them down to the thread of a brook and where each year we have complete control over the brood stock and the annual production. In these we must produce in increasing numbers our common pond and river fishes. As an illustration—in our state we have established one of these units. It is a narrow strip of land about a mile and one-fifth long and about one-eighth of a mile wide. On that strip we now have three ponds of a total water area of about 52 acres. We are building a dam and dividing one of these three ponds so that we will be able to put 25 more acres under water. This unit has been in operation since 1923, and in that time we have planted over half a million fish. This spring out of one pond we planted 70,000 hornpout that would run from five to seven inches in length. That unit is a small one. We will establish others that are larger. The time will come in many states when we can have ponds anywhere from one to five hun-

dred acres in size that can be operated in this way, and in them we can produce what you may call the common or garden variety of fish, I believe that if any commissioner will study the number of people who buy licenses to fish in his state he will find that by far the majority of these licensees are the fishermen of ordinary means, and that your so-called game fishermen are a vociferous minority.

The second phase of this work is what, for the sake of a better designation, I would term salvage work. I mean a system of trapping fish out of waters in which the public is prohibited from fishing, and the placing of them in open waters. We have operated such a system in our state for a number of years, and Connecticut is also another splendid exponent of this particular line of work. In every state we have a large number of municipal water supplies and other privately owned reservoirs in which all fishing is prohibited.

The matter of adequate water supply is of the most vital importance to our people, and the result is an increasing number of our lakes and ponds is being taken over as water supplies. The policy of the state and local water boards is to exclude the public from fishing in such waters and to prohibit trespassing on very sizable watersheds. Our anglers look over into this promised land, as it were, which they regard as teeming with the milk and honey of fish life, and naturally they are very restless, and they importune local water boards for an opportunity to fish, to say nothing of bringing pressure on the state officials who have control of the matter. But the protection of water supplies is one of the most sacred obligations of any municipal or state governments. Therefore if we can work out a plan in the various states by which each fish and game department shall be equipped with adequate traps, we can during the spring and the fall go on these water supply areas and trap out the fish. This need not be done every year; the best idea would be to lay your municipal water supplies out on a system running across the state, so that for example in a given year we can take Series A, the next year Series B, the next year Series C; and if that exhausts the possibilities, Series A can be tackled again the fourth year. There is no doubt that the results of such a plan will be remarkably successful, if your experience parallels that of our state. A large proportion of the fish so taken is matured brood stock.

Compared to the cost of operating a fish hatchery, and having in mind the character of the stock obtained and the numbers which can be taken out of these reservoirs on such a system as I have described, here is a phase of our work throughout the country that is in its infancy. Not only that, but the financial aspect of the matter is interesting. The trapping of the fish out of these water supplies appeals to the imagination of the local anglers, and we find little difficulty in getting local fish and game clubs in the areas where the operations are to be carried on to dig up the money to meet the cost of the job. I simply want to leave with

you this suggestion: that we all in our respective fields should pay more attention to the common food fishes of our inland waters; that while carrying on our work with the trout and other game fishes we should keep constantly in mind the welfare of the man of moderate means who wishes to go afishing.

## REPORT OF THE VICE PRESIDENT OF THE DIVISION OF PROTECTION AND LEGISLATION.

By Lee Miles.

Mr. President And Fellow Members Of The Society: In the preparation of this report I desire to submit, on the subject of protection and legislation, matters which, in my opinion, are worthy of consideration.

Drainage projects organized and put into execution throughout the Mississippi Basin from Canada to the gulf have wrought great damage to the supply of fishes of every species known to that locality. Many of these drainage projects have been failures from an agricultural standpoint, but equally detrimental to the supply of fish as if it had been a success from an agricultural standpoint.

The constant drainage of various areas heretofore known as lakes, bayous, lagoons and marshes for agricultural purposes have lowered the water level throughout the Mississippi Basin a few inches. As a result of this the annual rainfall has decreased; so that as a general result many lakes and ponds heretofore furnishing a water supply throughout the entire year have become stagnant, and in many instances the evaporation of water is so complete as to destroy all of the fish in many of the lakes and ponds. This epidemic of drainage has extended throughout the Mississippi Basin with its tributaries and constitutes such a serious menace to the production of fishes without giving corresponding results from an agricultural standpoint and it constitutes a condition worthy of government interference, provided there is a ground that would justify the government taking jurisdiction.

Another matter that is worthy of the attention of all conservationists, is pollution of various waters of the nation. This is especially true in the vicinity of streams in oil fields. Usually in newly developed oil fields there is a vast amount of crude oil going to waste. Possibly the greatest source of stream pollution comes from various machinery plants emptying their oil waste and other objectionable matter into nearby streams. This is damaging to fish life and damaging to parasites upon which small fishes feed. This covers the entire nation but is not so prevalent in the younger states as in the eastern states. As a rule this condition could be prevented by a Federal law more effectively than by a state law. It appears that the government could easily acquire jurisdiction to remedy this evil where the pollution is drained into a stream

that is interstate. I comprehend that the government's jurisdiction in aiding in the control of flood waters is based upon the theory that the water is interstate, and that it is unfair for one state to make all the expensive preparation for taking care of the flood waters poured in from another state. Federal jurisdiction would be equally applicable in the control of pollution of interstate streams. I think there is no question but that the government has entire jurisdiction toward the control of oil pollution on the coast lines.

It occurs to the writer also that effective legislation might be enacted by the various states, by enacting a measure authorizing the conservation department to set aside suitable areas for refuge, in which no fishing might be done, by suitable preparation made for the propagation of fish in these refuges and protection of them until they reach such a size that they can protect themselves from their natural enemy. This might also be done on behalf of the Federal government, as it has been done at least in one instance. We could have, with considerable profit, fish refuges as well as game refuges.

## REPORTS OF STANDING COMMITTEES.

### REPORTS OF THE COMMITTEE ON RELATIONS WITH NATIONAL AND STATE GOVERNMENTS

MR. PRESIDENT AND MEMBERS OF THE SOCIETY: Your committee on Relations with National and State Governments calls attention to an important conference held at Lansing, Michigan, on March 3d of this year, called by Governor Fred W. Green, of Michigan. His object was the consideration of ways and means to conserve the fisheries of the Great Lakes. The states represented were Illinois, Indiana, Michigan, Ohio and Pennsylvania. United States Commissioner Henry O'Malley, and other officials of the Bureau of Fisheries were also present and took part in the deliberations. The States of New York, Minnesota, Wisconsin and Provinces of the Dominion of Canada bordering on the Great Lakes, were not represented, although invited to attend.

As a result of the conference the International Fisheries Conservation Council of the Great Lakes was formed, Governor Green of Michigan, being chosen chairman for the ensuing year. The next meeting of the council was set for the first half of February, 1928, unless occasion requires holding an earlier meeting.

In opening the conference Governor Green was asked to preside but asked that United States Commissioner O'Malley act as chairman. Certain regulations governing fishing gear, sizes of fishes, and the taking of spawn were discussed and approved, as was also the matter of pollu-

tion control. The consensus of opinion was, that provision for the collection of fishing statistics should be made by the states in such form that statistics of one state might be compared with those of other states adjoining the lakes, so the trend of the fisheries could be determined. It was recommended that the authorities administering the laws governing the taking of fish in the Great Lakes, should be given power to promulgate and enforce additional regulations necessary to maintaining the fisheries.

Attention was called to the fact that at present five separate governments are making the laws for one of the lakes. The solution of the problem, it was thought, would be to delegate powers to the executive branches of the governments with authority to change regulations in order that proper co-ordination of effort could be promptly secured, instead of depending on slow legislative action. It was agreed that the fisheries of the Great Lakes are threatened with exhaustion, and that co-ordination of effort is necessary to save them. Your committee believes the members of the society are interested in the ultimate outcome of the above mentioned conference.

Your committee recommends that efforts should be made to secure a uniformity in the open season for the taking of fish from streams that flow from one state into another, and on streams that form the boundary line between the states. The same would apply to inland lakes that are not wholly within a state.

The attention of the members of the society is called to the fact that proper provision has as yet not been made by Congress for the enforcement of the "Hawes Law" for the protection of black bass, and therefore recommends that the society continue its efforts toward securing the same.

Your committee also believes that the matter of hunting and fishing license fees as they relate to non-residents of a state be given some consideration. There seems to be a tendency to raise the fees to usurious rates. The average non-resident of a state takes less fish or game than the average resident angler or hunter. It would seem therefore, only fair that the fee for angling or hunting licenses should be based more on the amount of fish and game a non-resident takes. At present there seems to be a tendency to exclude non-residents instead of welcoming them.

Respectfully submitted,

GEORGE N. MANNFELD,
*Chairman.*

## REPORT OF THE AUDITING COMMITTEE.

MR. AVERY: The Auditing Committee report that they have found the accounts correct, and they approve them and sign the report—James A. Laird, Chairman; C. P. Peterson; and George C. Waggoner.

The report of the Auditing Committee was accepted.

## REPORT OF THE FINANCE COMMITTEE.

Mr. Avery: Your Committee on Finance begs leave to report as follows:

We recommend that allowances be made for clerical expenses for the various offices for the year 1927-8 as follows:

Office of the Secretary, not to exceed $75
Office of the Treasurer, not to exceed $50
Office of the Librarian, not to exceed $30

We recommend that the investment of the Permanent Fund of the Society be changed from the Consolidated Railroad of Cuba to Bush Terminal Bonds, or Remington Rand First Preferred stock.

We recommend that subscriptions be requested for a special fund for compiling and printing a catalogue of the publications of the society and that the Librarian be authorized to arrange for such work as soon as funds are available.

Respectfully Submitted,

FREDERICK C. WALCOTT,
CARLOS AVERY,
*Committee.*

I may add in explanation of the recommendation of expenses for clerical allowances that our by-laws provide that no expenditure may be incurred by any officer for clerical services without previous authorization from the society, consequently it is necessary to have that provided for.

As to the change in the investment of the Permanent Fund, the committee recommends this because the stocks in which the funds are invested at the present time are foreign securities, which may be permanently valuable and may not. It is thought advisable that they should be changed for domestic securities.

The committee informally suggests that a subscription list be started here at this meeting for the compilation and printing of a catalogue of the publications of the society, in order that something may be actually accomplished. We have been

talking about this for years without doing anything. Mr. Walcott, Chairman of the Finance Committee, has started the subscription with the very generous contribution of $50, and a few other smaller subscriptions have been received. I would move, Mr. Chairman, that this subscription list be opened and that the members be given an opportunity while here to contribute whatever they see fit for this purpose in order that the work may be started.

The report of the Finance Committee was accepted.

PRESIDENT TITCOMB: The subscription list to which Mr. Avery has referred will be available at any time, and amounts from one dollar up to a million will be accepted. It will be quite an expensive job to get out such a catalogue, but it will be invaluable to all of you, and I believe it will result in a larger distribution of our publications.

MR. WALCOTT: I think the purposes of this subscription might be amplified a little. There is no classified index now for the society's publications. Without such a classification or index the publications are not nearly so readily available for reference, and that is the purpose of the subscription—to put it so that everybody can find his subject immediately, without the tedious process of going through a long list of publications. It will quadruple the value of these publications to have an index, and I hope it can be done promptly so that we can have it done under the supervision of the Department at Washington, which has already done a great deal of this work.

### REPORT OF THE COMMITTEE ON TIME AND PLACE

MR. HAYFORD: We have for the next convention, 1928, twenty-four invitations. The joint committee has considered these invitations very carefully. In view of the fact that we met in Quebec, Denver, Mobile and Hartford the last four years, we feel that the next convention, in all fairness, should go west of the Mississippi River. The committee, therefore, unanimously recommends Seattle for the next meeting.

We have not decided on the time; we feel it would be better to leave that to the Executive Committees of the two associations.

The report of the committee was adopted.

## REPORT OF THE COMMITTEE ON RESOLUTIONS.

### Compensation Of Fish Culturists.

Whereas, state and federal fish cultural employees receive very meagre salaries in comparison to that paid for similar work elsewhere, and

Whereas, fish culture is an exact science requiring the best efforts of skilled and highly trustworthy employees

*Therefore, be it resolved,* That the American Fisheries Society urges concerted action through State Legislatures and Congress to secure proper rates of pay.

### Fishery Statistics.

Whereas, legislation regulating and restricting the fisheries should be based on scientific facts and

Whereas, one of the most important instruments to this end is a proper system of fishery statistics which will disclose the condition and trend of each fishery and the need for legislation,

*Therefore be it resolved,* That the American Fisheries Society urge each state to provide adequate legislation for the collection of fishery statistics.

### Travel Expense Allowance.

Whereas, employees of state and federal agencies are greatly benefited by attendance at fisheries meetings

*Be it resolved,* That the American Fisheries Society urge that permission be made in federal and state budgets for travelling expenses of fisheries employees to such meetings

That in so far as practicable copies of this resolution be sent to state budget officers and the U. S. Bureau of the Budget.

### Great Lakes Fisheries.

Whereas, the fisheries of the Great Lakes are being severely depleted with actual danger of complete exhaustion of certain important species, and

Whereas, under the divided jurisdiction of the several states and the province of Ontario little progress is being made in the passage of adequate conservation laws,

*Therefore, be it resolved,* That the American Fisheries Society urges that the several states enter into an agreement to urge upon the Secretary of State the negotiation of a treaty with Canada providing for an International Great Lakes Commission to study the conditions and trend of its fisheries and promulgate such regulations as are necessary for their conservation.

### Puget Sound Salmon Fisheries

WHEREAS, the great need for protection of the salmon fisheries in boundary waters between the State of Washington and the Province of British Columbia has been well demonstrated, and

WHEREAS, past experience has shown that state and provincial governments involved are unable to handle this matter in a satisfactory manner

*Therefore, be it resolved,* That the American Fisheries Society hereby goes on record as favoring a treaty between the United States and Canada for joint control of the salmon fisheries of the boundary waters of Washington and British Columbia.

### Appreciation

The American Fisheries Society wishes to record its deep appreciation of the royal hospitality accorded its members by the Connecticut Commission and especially by its able superintendent, John W. Titcomb.

The Society also expresses its appreciation to the press of Hartford for the space given to its meetings.

The resolutions were adopted by a rising vote.

## REPORT OF THE COMMITTEE ON NOMINATIONS.

### Officers For 1927-28:

*President* .......... DR. EMMELINE MOORE
*Vice-President* .......... C. F. CULLER
*Secretary* .......... CARLOS AVERY
*Treasurer* .......... T. E. B. POPE
*Librarian* .......... JOHN W. TITCOMB

*Vice-Presidents of Divisions*

*Fish Culture* .......... JAMES A. LAIRD
*Aquatic Biology and Physics* .......... DR. GEO. C. EMBODY
*Commercial Fishing* .......... CHARLES R. POLLOCK
*Angling* .......... TED COTTRELL
*Protection and Legislation* .......... LEE MILES

*Executive Committee*

L. H. SPRAGLE, *Chairman*
E. LEE LECOMPTE
W. E. ALBERT
THADDEUS SURBER
HONORE MERCIER
J. B. DOZE
E. W. COBB
I. T. QUINN
JOHN N. COBB

*Committee on Foreign Relations:*

F. C. Walcott, *Chairman*
Henry O'Malley
J. A. Rodd
Dr. H. S. Davis
C. P. Peterson

*Committee on Relations with National and State Governments:*

N. R. Buller, *Chairman*
Swepson Earle
William C. Adams
C. J. Meredith
D. H. Madsen
Lewis Radcliffe

*Publications Committee:*

Dr. D. L. Belding
John W. Titcomb
Dr. George C. Embody
Dr. H. S. Davis

The report of the Nominations Committee was adopted unanimously and the nominees declared elected.

Retiring President Titcomb: Ladies and Gentlemen, the annual meeting of the American Fisheries Society is about to be drawn to a close. The only matter of business to occupy our attention at this time is for me to turn over the gavel of my office to my successor, Dr. Emmeline Moore. I have not prepared any speech for this occasion, but I wanted to say that this is a case where the office seeks the woman and the woman honors the Society by accepting the office. Dr. Moore, I take great pleasure in turning over the gavel to you. (Applause.)

The President Elect, Dr. Emmeline Moore: I want to express my appreciation of this great honor. The honor is great because I succeed a great president. (Applause.) And the honor is great because sixty years ago, or about that, when the Society was organized, the membership were so broad in their views that they did not regard it necessary to make special provision for untried presidential femininity. In the years that have elapsed it has not been necessary to make any other rule, so that to-day my nomination went through without the necessity of changing the rules.

I feel particularly honored because I am confident that at this time we are entering a new era in fish culture. I am sure that the three days' sessions held here and in the field indicate that a new effort has begun in scientific fish culture. As chief executive of this piscatorial society I shall endeavor to maintain harmony between the devotees of the lowly, crawling, humble worm—the worm baiters—and the aristocratic fly baiters.

Whereupon, the Fifty-Seventh Annual Meeting of the American Fisheries Society was adjourned.

# In Memoriam

## DWIGHT LYDELL

By Fred A. Westerman

Dwight Lydell was born on a farm near Jamestown, New York, September 26, 1861, and passed away at Comstock Park, Michigan, on February 8, 1927. When he was ten years of age the family moved to Paris, Mecosta County, Michigan, at that time the northern terminus of the Grand Rapids and Indiana railroad. Here the father and seven growing boys hewed a farm out of the virgin forest within one-half mile of the place where the State Fish Hatchery was established in 1881. Here he grew to manhood well inured to the hardships and primitive conditions that were the common lot of the early settlers.

About 1885 he was first attracted toward fish cultural work in connection with the collection of whitefish spawn at Belle Isle, Grassy Island and Fort Wayne at Detroit, receiving here his first training in the vocation that he was destined to follow through life. These operations provided only temporary employment and young Lydell, of an adventurous nature, was ready and willing to attempt whatever opportunity offered. However, a discouraging season's experience farming convinced him that tilling the soil was not to his liking. He tried sailing on the Great Lakes for a season but the urge to learn more of practical fish culture lured him back and after about the year 1890 he was in the constant employ of the Michigan Fish Commission, later merged with the Department of Conservation.

When attention was first attracted toward the possibility of propagating black bass and the need therefor became urgent, Lydell became interested in this field. His early work along this line was carried on at Cascade Springs, on the Thornapple River, Kent County, Michigan. It was here that he established the fact that the male small mouthed black bass prepared the nest and stood guard during the incubation period and the early life of the baby bass. In 1897 Lydell was sent to the village of Mill Creek, now Comstock Park, five miles north of Grand Rapids where a small tract of land had previously been purchased along the stream of the same name. The early work at Mill Creek met with many obstacles. Lack of sufficient funds hampered development, unusual summer floods wrought havoc. Determination, perseverance and an indomitable courage was about all there was left to show for the first season's

work. All the while, however, more of the habits of the black bass were unfolded to his observing gaze and his inventive genius devised practical equipment to meet the problems he had to solve.

Under his able direction the Mill Creek hatchery has been developed until today it stands without question the finest bass hatchery in the United States. It may fairly be said to be the monument he leaves to posterity. Lydell's success in handling black bass attracted the nation-wide attention of pisciculturists, and Mill Creek became the Mecca toward which ichthylogists turned. During 1926, while sorely afflicted by the pernicious malady that struck him down, he demonstrated the practicability of producing two crops of fingerling fish in the same pond by taking species that spawn and develop at different seasons of the year.

For the past twenty-five years he served as Assistant Superintendent of State Fish Hatcheries, in which capacity he had a large part in developing the state's several bass hatcheries. In 1898 he became a member of the American Fisheries Society and in later years contributed numerous articles on practical fish culture, particularly as it pertains to the propagation of black bass. These have been published in the annual reports of the Society.

Not many men in this world carry on out of sheer devotion to duty. With most of us, labor is a means to the end of providing a livelihood. But Lydell was of the select few, for truly he put his heart in his work. His constant genial nature and unflagging interest showed that there was no drudgery in all of it for him, but it was in the nature of a great adventure frequently unfolding new and interesting things in his chosen field. He learned much in Isaac Walton's great outdoor university and the knowledge he thus acquired has contributed lastingly to the progress and development of fish culture and the betterment of mankind.

**ROBERT FORSYTH**

**CALEB HALEY**

**C. A. JACKWAYS**

**JOHN W. OPDENWEYER**

**GIRAUD F. THOMSON**

# PART II

# PAPERS AND DISCUSSIONS

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# THE PENNSYLVANIA PROGRAM FOR THE ELIMINATION OF POLLUTION OF WATERS

By Nathan R. Buller

*Commissioner of Fisheries and Member of the Sanitary Water Board*

The Sanitary Water Board, as created by statute in 1923, consists of the Secretary of Health, Chairman; the Commissioner of Fisheries; the Secretary of Forests and Waters; the Attorney General, and the Chairman of the Public Service Commission. This board is charged with the administration of state laws relative to the discharge of substances detrimental to fish life, the discharge of sewage and of sewerage projects. It is clothed with investigatory authority and the appropriation acts provide for cooperation of the board with persons, corporations or municipalities in determining reasonable and practicable means for abatement of stream pollution.

The objectives of the board include—

(a) To administer the statutes with even handed justice so as to serve the best interests of the commonwealth, its municipalities, its corporations and its people.

(b) To accomplish in a reasonable manner the best possible results by the least expenditure of public and private funds.

(c) To preserve and extend the now unpolluted waters of the state.

(d) To provide and safeguard sources of public water supplies.

(e) To protect and preserve suitable streams for fishing.

(f) To secure wherever practicable, the abatement of all stream pollutions harmful to public interests.

The interest of the public in the condition of the water courses has rapidly increased of recent years because of the improved highways, the automobile, fishing, hunting, camping, and other outdoor recreations.

The growth of towns to cities, the establishment of new towns and the lavish use of water in the American household has likewise created an ever increasing demand for public water supplies, which, for the protection of health, must be pure and wholesome.

Hence arises the ever increasing need for clean streams. But simultaneously occurs the greatly to be desired growth of public sewer systems in our towns and development of the industries of the state and utilization of its mineral resources all of which tend to increase the load upon the streams resulting in a very complicated problem before the Sanitary Water Board.

Pennsylvania is a large and great state. It embraces over 45,000 square miles of area, has nearly 10,000,000 population, of whom all but 1,000,000 live in nearly 1,000 municipalities, of which about one-half are sewered in whole or in part.

About 6,500,000 people in Pennsylvania are served with public water supplies, mostly derived from surface sources. In Pennsylvania there are at least 2,500 industrial plants producing liquid wastes which must be discharged to the streams. These industries represent a capital investment of over $1,000,000,000 and their output is valued at over $1,500,000,000 a year.

There are about 100,000 miles of named streams in Pennsylvania which flow at an aggregate average rate of 2,600,000,000 gallons an hour.

These figures give an idea of the magnitude of the problem confronting the Sanitary Water Board and show the necessity for careful study and for establishing policies which will be sane and practicable if the best interests of the whole commonwealth are to be subserved.

The board early established and is successfully carrying out certain basic principles of a comprehensive plan of which the chief are:

(a) Classification of streams.
(b) Cooperation with municipalities for the progressive construction of sewage treatment works.
(c) Cooperation with groups of industries for solving industrial waste disposal problems, and
(d) Cooperation with adjacent states for control of pollution of inter-state streams.

The resolution for classification of streams is as follows:

WHEREAS, the degree of pollution of the waters of the state varies widely from the pristine purity of a small stream flowing through a virgin forest to the grossly polluted stream draining a valley given over to intense municipal and industrial development, and

WHEREAS, such differences in condition and the present and probable future use of the streams must be recognized in determining the required degree of treatment of sewage and industrial wastes, and

WHEREAS, the natural powers of streams to inoffensively assimilate and dispose of polluting matters by dilution must be utilized so far as compatible with the general interests of the public in order to establish a practicable and economical program for stream control, therefore

*Resolved*, That the waters of the state be classified as follows:

## RELATIVELY CLEAN AND PURE STREAMS

CLASS "A"

Streams in their natural state probably subject to chance contamination by human beings but unpolluted or uncontaminated from any artificial source, hence generally fit for domestic water supply after chlorination, will support fish life and may be safely used for recreational purposes.

## STREAMS IN WHICH POLLUTION SHALL BE CONTROLLED

CLASS "B"

Streams more or less polluted, where the extent of regulation, control, or elimination of pollution will be determined by a consideration of (a) The present and probable future use and condition of the stream; (b) The practicability of remedial measures for abatement of pollution, and (c) The general interests of the public through the protection of the public health, the health of animals, fish and aquatic life, and the use of the stream for recreational purposes.

CLASS "C"

Streams now so polluted that they cannot be used as sources of public water supplies, will not support fish life and are not used for recreational purposes and also from the standpoint of the public interests and practicability it is not now necessary, economical or advisable to attempt to restore them to a clean condition; and further,

*Resolved*, That all artificial pollution of Class "A" streams shall be prohibited and any sewage or industrial wastes on the watershed shall be treated to such a degree that the effluent shall be practically free from suspended matter, non-putrescent and disinfected and that recreational use shall not be sanctioned within prejudicial influence of water works intakes, and further

*Resolved*, That the degree of treatment of sewage and industrial wastes discharged into Class "B" streams shall be determined for each particular stream or portion thereof after consideration of the general interests of the public and the economics of the paticular case, and further

*Resolved*, That sewage and industrial wastes may be discharged into Class "C" streams; provided, however, that such discharge shall not create any public nuisance or menace to health.

In accordance with the policy for Class A streams, wardens of the Board of Fish Commissioners have made actual traverse of the clean streams in certain counties, these data have been checked by engineers of the Department of Health and as a result the board so far has designated 4,575 miles of streams as Class A in seven counties. Abatement of first source of their pollution has so far added over 90 miles to this length. Surveys of streams are now under way in eleven more counties which will markedly increase the mileage of known Class A streams.

It should be borne in mind that on any given stream no matter how clean it may appear, in accordance with the definition of a Class A stream only the portion of the stream above the first point of pollution can be designated as Class A and all the stream below that point must be Class B.

The total mileage of the clean streams in Pennsylvania will be greatly in excess of the mileage of Class A streams.

In accordance with the above resolution as various cases come before the board with reports of field investigation, office and ofttimes laboratory study, decisions are reached by the board only after a due consideration of the use and condition of the receiving body of water, practicability of remedial measures and the economics of each particular case.

In the problem of disposal of municipal sewage, finances and constitutional limit of borrowing capacity are absolute controlling factors.

The rapid growth of our municipalities demands constant enlargement of their existing public works, establishing new facilities and services for the protection and comfort of the citizens. To meet all real needs would far exceed the available income of the town. It is common practice for municipalities to build their major public works from loan funds.

These conditions require the Municipal Council to use wisdom and prudence in allocating the current revenue and borrowing capacity among the manifold pressing demands in proportion to real benefits obtained from the expenditure. Therefore, funds spent for the treatment of sewage to a higher degree than is needful prevents the council from carrying out other essential public projects.

Where several sewered municipalities are situated along a stream of inadequate rate of flow to inoffensively assimilate their untreated sewage the condition of the stream becomes intolerable because of overload. This creates the impression in the public mind that all sewage should be thoroughly "puri-

fied." But if each of these municipalities should treat its sewage only to that extent needed to not unduly deplete the oxygen in the water at and below the point of discharge then the stream can be restored to a cleanly condition without the exorbitant expense of all of the sewage actually being "purified."

Where municipalities are on the same drainage area and contiguous or reasonably close together, it is generally economical for them to join together in a cooperative sewerage project for a system of continuous intercepting sewers to convey all the sewage to single sewage treatment works.

Continuous intercepting sewers also more effectively protect the head water stream as then they do not receive even sewage effluent.

To meet the very particular matter of municipal finance, the total expense of a sewage disposal project in many cities must be distributed over a period of years through the adoption of a financial program for the progressive construction of the intercepting sewers, pumping station, treatment works and appurtenances. The length of time depends upon the urgency of the case and the financial condition of the municipality.

The engineers representing the Sanitary Water Board have been quite successful in collaborating with engineers of municipalities in formulating financial programs within the ability of the municipality to provide for the construction of the needed works over a period of a few years. When such a program has been adopted by the council of the municipality, it is submitted to the Sanitary Water Board with application for approval and if satisfactory to the board, permits issued thereafter are in accordance with the adopted program.

When the economics of the problem of industrial waste disposal is considered we are confronted with an entirely different situation.

The disposal of industrial waste is directly connected with the cost of living to every citizen of the state. A very personal matter.

The price which a man must pay for a load of bricks to build his house, a ton of coal to warm it, a pair of shoes to cover his feet and the ream of paper upon which his letters are typed includes all the costs of manufacturing the bricks from the clay, mining the coal, tanning the leather and turning a tree first into pulp and then into paper. These costs must include costs of waste disposal.

The public always have protested against the high cost of their necessities although they are generally silent concerning

the cost of luxuries. Anything which tends to reduce the cost of commodities is deemed a public benefit while those things which increase the cost of living are condemned by the public. It is, therefore, much to the public interest to solve the problem of disposal of industrial wastes in the most economic manner—both as to finding out how to do it and also as to applying the principles when they are known.

It would not be reasonable or economical to expect any one concern engaged in a certain industry to attempt to solve these problems for the benefit of their competitors in the same kind of business. Even if they succeed, the conditions in the one particular case might or might not be able to solve the problem elsewhere.

So it is evident that a better procedure is for concerns engaged in a certain industry to join together in a thorough scientific study and solve the common problems. Then each concern can apply the basic principles thus found to the solution of their own particular problem.

But such a study is not confined to the mill or factory but involves investigation of the effects of the industrial wastes upon the streams. In some cases whole river systems must be studied. This is a phase of the question which involves the public authorities.

These premises naturally lead to the conclusion that the economical solution of the industrial waste disposal problem can best be attained through the cooperation of the state and industries in groups in a spirit of good faith on both sides.

The Sanitary Water Board has put into practice this principle of cooperation with industry.

In 1924 negotiations were begun with the leaders of the leather tanning industry in Pennsylvania. The outcome was the execution of a formal agreement dated July 30, 1924, between the Sanitary Water Board and companies operating tanneries in the state.

This agreement created the "Tannery Waste Disposal Committee of Pennsylvania" consisting of three chief engineers and three chief chemists of companies parties to the agreement and the chief engineer of the Sanitary Water Board as chairman. The agreement provided for the creation of a fund of $35,000 contributed by the tanning companies in proportion to the capacity of their tanneries expressed in pounds of green salted hides a day. The Sanitary Water Board has contributed to date about $5,000 toward this work, chiefly through the salary of a chemist assigned for that purpose.

The fund is being expended by the committee in research along three main lines as follows:

(1) Investigations in a research laboratory to determine the characteristics and relative strengths of the 15 wastes which are produced during processes of leather tanning. Also experiments to ascertain if favorable reactions could naturally be obtained by mixing certain of the wastes together preliminary to treatment.

(2) The erection, operation and study of the sedimentation parts of a full scale experimental treatment works at a tannery situated on the head waters of the Clarion River.

(3) The establishing of five gauging and sampling stations along the 12 miles of the Clarion River below the experimental works in order to determine the assimilating power of a stream for tannery waste, untreated and treated to varying degrees.

The laboratory investigations disclosed the wide range of variation in the character of the several ingredients and showed that marked improvement was obtained by the mere mixing and permitting reactions between certain of the alkaline and acid wastes.

The operation of the first part of the experimental works demonstrated that by using reaction tanks for certain intermittent wastes, adding the supernatant thereof to the continuous wastes, using a solution of alum as a precipitant with subsequent sedimentation—a very marked reduction was obtained in total and suspended solids, color and polluting strength. However, an excessive amount of watery sludge was produced amounting to as high as 10% of the volume of tannery waste treated.

Due to a closing down of a railroad passing the tannery where the investigations were conducted, the plant had to be dismantled and is being reerected on improved lines at another Pennsylvania tannery where the experimental work will be continued and expanded.

The stream studies demonstrated the ability of a stream to inoffensively assimilate much more waste when discharged over 24 hours than during the normal eight or ten hours or in other words that continuous instead of intermittent discharge is equivalent to the artificial treatment of the waste to effect 50 to 70% improvement.

The second cooperative project was inaugurated in 1925 through the creation of the "Pulp and Paper Waste Disposal Committee of Pennsylvania," consisting of engineers and chemists of that industry and the chief engineer of the Sanitary Water Board as chairman.

This committee made a report to the Sanitary Water Board setting forth a number of the already solved problems of pulp and paper waste disposal and the report stated that eight Pennsylvania mills during the past ten years have expended $2,500,000 for apparatus for the removal of materials from pulp and paper mill waste waters and to research in connection therewith.

For the still unsolved problems the committee recommended cooperative investigations.

Accordingly, the Sanitary Water Board submitted a draft of agreement to the executives of the Pulp and Paper Industry in Pennsylvania which was approved by them and the formal agreement dated November 17, 1926, has been executed to date by 24 companies who represent about 80% of the entire pulp and paper output of the state.

Under the agreement the commitee has been enlarged to include representatives of many types of mills. The laboratories of the Sanitary Water Board and of seven paper mills were placed at the disposal of the committee for conducting its researches.

Preliminary reports of the work under way in these laboratories showed that there was very little information on which to base the more important part of the research so that it is necessary to first do pioneer work and create new laboratory methods in order to put the investigations on a firm, sound, scientific basis.

The Sanitary Water Board, under another agreement, is also investigating the subject of laundry waste treatment, heretofore deemed an unsolved problem and the outlook for a practicable solution is very good.

The pollution of an interstate stream in one state which harms the users of the stream in another state is a matter beyond the jurisdiction of the authorities of the harmed state. Abatement may be attainable through a suit in the Supreme Court of the United States but this is a tedious, costly and unpleasant procedure. The Sanitary Water Board has solved this problem as follows:

The Delaware River forms the boundary between Pennsylvania and New Jersey. In July, 1922, the Departments of Health of these two states executed an agreement erecting uniform policies as to degree of treatment of sewage prior to its discharge to the river.

The Sanitary Water Board at its first meeting approved this agreement and has used its provisions in all sewerage permits subsequently issued.

Early in 1924, representatives of the Sanitary Water Board and of the Departments of Health of Ohio and West Virginia met in conference to consider the adoption of an interstate agreement applicable to the watershed of the Ohio River. Subsequent negotiations resulted in a form of agreement which was approved by the Board and executed on November 17, 1924. The signatory authorities to this agreement agreed to cooperate with each other to carry out a policy for the conservation of the interstate streams within Ohio, West Virginia and Pennsylvania.

A similar form of agreement was executed in March, 1925, between the Board and the Department of Health of New York State, providing for carrying out a policy for the conservation of the interstate streams of Pennsylvania and New York, including the prevention and abatement of undue pollution thereof to the end that the said streams may be rendered and maintained increasingly useful to the citizens of the two states.

The Department of Health of Kentucky requested permission to become a party to the 1294 Pennsylvania, Ohio and West Virginia agreement and on February 18, 1926, a supplemental agreement was executed so doing.

In the latter part of 1926 a second supplement was executed which made the Departments of Health of Pennsylvania, New York, Maryland, West Virginia, Ohio, Indiana, Illinois, Kentucky and Tennessee, parties to this agreement.

Under this agreement and its supplements, a Board of Engineers has been created consisting of the chief engineers of the above named State Health Departments and this board has organized and made a report to the Health Commissioners proposing policies under the agreement which will make the board what is believed to be the first de facto Rivers Board in the United States.

As a result of actual experience it can be said with assurance that these interstate stream conservation agreements have brought about a splendid spirit of cooperation between the authorities of the several adjoining states and this has resulted in the abatement of a considerable number of pollutions of interstate streams, which lacking such agreements, would probably have only been made through litigation in the Federal Courts or even in the Supreme Court of the United States.

## CONCLUSION

As a result of four years' experience of the Sanitary Water Board of Pennsylvania in the administration of statutes rela-

tive to sewerage and stream pollution in accordance with a comprehensive plan, of which some of the major factors have been discused above, the board feels assured that sane conservation and prudent utilization of water resources can best be attained through cooperation of the state, its municipalities, its industries and its citizens.

Supplementing his paper, Mr. Buller said:

Before the creation of this Sanitary Water Board in Pennsylvania the matter of the pollution of waters came under different heads. For example, the Department of Health had authority over sewage, the Department of Fisheries over industrial wastes, and the Water Supply Commission over obstructions, such as coal dust, and so forth. By drastic legislation for fifty years each of these organizations had been trying to accomplish things, but we found that they were not accomplishing anything at all, hence the creation of this Sanitary Water Board, and its progress.

I am a great believer in co-operation. You gentlemen all appreciate the difficulty experienced in getting adequate legislation to correct these evils. Fortunately our health law in Pennsylvania is very good; we need no further legislation so far as the Department of Health is concerned. But when it came to getting legislation covering the industrial situation, while we have a law making it unlawful to turn anything into the stream which is detrimental to the waters thereof, we could never get any fine attached to it in excess of $100. In legislature after legislature attempts were made to have these fines made heavier, but it could not be done, and the result was that we were not getting anywhere. I believe in the cooperative way; if you can get to the real fountain head of all these corporations and polluters, as we call them, you can accomplish something. Every case that comes before the Sanitary Water Board for decision is placed in my hands with authority to act, and I have settled quite a number of these cases out of court.

# FLOOD CONTROL IN THE MISSISSIPPI VALLEY IN ITS RELATION TO LOUISIANA FISHERIES

By Percy Viosca, Jr.

*Director of Fisheries, Department of Conservation of Louisiana.*

When we consider that under primitive conditions about one-half of the State of Louisiana, an area comprising some fifteen million acres, was covered with water for at least part of the year, and that today this has been reduced to about ten million acres, we wonder what were the primary reasons for the reclamation of so large a proportion of this great flood plain from its annual inundation.

The idea of a rich virgin alluvial soil which needs no fertilizer is the first thought which comes to mind. Was that, however, the primary reason for the earliest settlement of Louisiana? Perhaps not, because a new country is always built up on its natural resources, and agricultural pursuits are developed as a secondary source of food supply, at first supplementing, and later gradually replacing the natural sources as the growing population depletes them. The early settlers found Louisiana abundantly rich in such resources, and because of her great areas of temporary or permanent wet lands, water-living creatures dominated the native species of this region. Then, as today, her wet areas were the most productive naturally, and waterfowl, fisheries and fishery products played no small part in the sustenance of Louisiana's pioneers.

Because of the inherent wealth of virgin Louisiana alluvial regions, the pioneers sought these lands and built their cabins or homes along the river banks, since here were the highest ridges in our great lowland basins. Owing to the richness of the soil in these periodically flooded areas, agricultural pursuits were a decided success and villages and towns sprang up and have evolved until today they have become the great population centers of our state. As a protection against these periodic floods, instead of building mounds or retiring to the highlands during the overflows, as did the Indians of this region, levees were found to be better suited to the needs of the white race, and these also have evolved until we have mountainous dykes so familiar to our inhabitants today. By means of these levees, built to hold the main rivers during flood stages within the same channels they occupy during low water, we have wrought many changes in the character of our state, for we have not only protected to a great extent, the better developed alluvial lands of higher level adjacent to the rivers, but

have in a great measure prevented this flood water from entering the extensive lowland basins where it normally deposited its fertility before the river stages lowered to such an extent that it could find an outlet to the sea. The shallow inland swamps above sea level, when filled only periodicaly by rainfall, do not possess the richness of the same area as when they are flooded by the rivers.

Thus man, by harnessing our rivers, has created new conditions of existence in the formerly wet areas, this resulting in a decided decline of the aquatic natural resources. Several million acres formerly suited to fish and other aquatic wild species have been made unfit for such creatures, yet are serving no other useful purpose, either because the land is not needed in these days of surplus crops, or because they cannot stand the tax necessary for reclamation, or because they are subject to the ever present menace of disastrous floods.

It is chiefly as a result of the building of levees, and not as a result of shooting and trapping, that our aquatic birds and mammals have suffered. On the other hand, moderate floods are not severe upon this wild life as is commonly supposed, while it recovers with startling rapidity even after severe floods. Just as our aquatic birds and mammals have suffered by our present and past means of flood prevention, reclamation and drainage projects, so have our fisheries, both marine and fresh water. This is sometimes not noticeable as in the case of the oyster, where artificial cultivation is supplementing the natural supply, or in some of our fisheries, where modern machinery and fishing tackle manned by an ever-increasing army of men, who often seek new and distant fishing grounds, have been keeping the supply equal to the increased demand.

The real reason, however, why Louisiana has not felt to any severe extent, a shortage of her fisheries resources, is because of the annual tendency of her rivers, particularly the Mississippi, to return the state to her primitive condition, and the history of crevasses has shown, that to a greater or lesser extent, they have succeeded from time to time.

While agriculture and industry have suffered greatly from the recent rampage of the Mississippi, let us try to look at this flood as an attempt by nature to return Louisiana and other parts of the valley to their virgin condition, and with this viewpoint, determine what benefits will accrue, and what lessons we can learn toward harnessing the streams of the Mississippi Valley so that we can derive most from the floods with the least harm to our native wild species.

FLOODS AND FISHERIES

The most obvious benefit resulting from an overflow on the lower Mississippi is the enrichment of the soil by deposition of fertilizer elements previously washed from the soils of two-thirds of the United States. This always insures fine crops with a minimum amount of work immediately following recession of the water. Only a small percentage of the fertilizer elements are deposited on the land, however, the balance being carried into the swamps, marshes, lakes, bays and shallow waters of the gulf. This in a very short time is converted through a biological succession into an inconceivably large supply of living plant and animal organisms, the fundamental food supply of our fresh and salt water food fishes, frogs, turtles, alligators, shrimp, oysters, fur bearing animals, and our ducks and other water birds. Those in the aggregate constitute perhaps the densest and richest wild fauna in the world, considered both from its commercial and recreational values. Ordinarily, most of this food material is carried out to sea, but when the levee system gives way and it is checked in its seaward course in the vast inland lakes recreated by crevasses, it fertilizes waters which are easily accessible to the fishing population of Louisiana and adjacent states.

The floods virtually create conditions in the formerly dried areas, similar, except for the mingling of species, to those in a fish hatchery. This hatchery instead of being only a few acres in extent, covers a great area. During the 1927 flood, it comprised some six million acres, or about one-fifth of the total area of the state. Since all of Louisiana streams are interconnected, the benefits of this gigantic fish hatchery and brood pond are statewide. Spreading over our swamps and farm lands, the fish formerly confined to our streams, propagate in inconceivable numbers and grow rapidly upon the abundant supply of micro-crustaceas, fresh water shrimp, crayfish, minnows, worms, insects and other live food available, as well as upon the dead animal and plant life destroyed by the floods. This results in an immense surplus of fish in our inland waters, and it almost becomes a patriotic duty for everyone to catch or eat fish, especially the big fish, because our streams have not the capacity to hold and feed all of the fish left in them when the high waters recede.

The fresh water commercial fish, such as the buffalofishes, the catfishes, the fresh water drum and the paddlefish, thrive in flood waters and the increase in their numbers and tonnage is almost inconceivable. River shrimp and crayfish, both of

which are highly prized delicacies in the lower Mississippi Valley, also show phenomenal increases during every flood, and turtles and frogs which suffer so severely during every drouth obtain a new lease of life.

The fresh water sport fishermen find exceedingly fine fishing, as soon as the waters recede, in all of the bayous and inland lakes and streams. Black bass, crappie, barfish and sunfishes become especially abundant after every flood.

In the salt water areas also, the floods on the whole are decidedly beneficial. It is true that on the coast some of the oyster beds close in are temporarily destroyed by excessive amounts of fresh water, but likewise many old reefs are rehabilitated. Even those oysters that are destroyed in turn serve as food for other organisms or as fertilizer for the minute aquatic plants which themselves serve as food for the oysters on the newly created reefs a short distance away. Under the water a well established biological cycle prevents the loss of the nitrogenous and other valuable elements, which cannot be dissipated into the atmosphere by fires as in the case of forests or land crops. The result in the case of the oysters is largely a shifting of certain fishing grounds but the total oyster crop is decidedly increased. The fresh water also destroys the army of Purpura or conchs, and otherwise retards the activities of other natural enemies of the oyster which thrive in sea water.

Salt water shrimp are always abundant in the gulf off the passes of the Mississippi where they feed on animal and vegetable debris deposited in the salt water by the river. As soon as the floods subside, young salt water shrimp migrate in great schools into those tide level lakes and bays where the debris has also been deposited, and there they become more accessible to the shrimp fishermen who cannot always venture into the open gulf or to more distant fishing grounds. The salt water shrimp also seem to benefit by the destruction of a certain parasitic disease which does not affect them in fresh water, and those shrimp which are grown in water of low salinity develop a more delicate flavor than shrimp maturing in sea water.

What has been said of the shrimp, also applies to the blue crab. While the young crabs are born in water of high salinity, they thrive best and grow to maturity faster in sea level fresh water, and our most abundant crops of hard and soft shelled crabs are always produced during the flood years on our rivers.

Because of a great increase of food supply, the salt water fish indigenous to Louisiana also benefit greatly by floods, and the people of the affected regions along the coast who make a livelihood by fishing quickly recover from any temporary setback, because during the floods there is virtually a natural close season during which the fish are growing rapidly due to the added food supply. After every flood the salt water anglers find their paradise because of the abundance of salt water game fish in the sea level lakes, bays and passes.

Another matter which has a direct relation to our fisheries must not be overlooked. The breeding places of the coastal mosquitoes become totally annihilated in all areas affected by the flood waters, and the restoration of the wetlands to their primitive condition, with a healthy growth of aquatic plants (incidentally the best foods for ducks and muskrats), and a heavy supply of Gambusia and other carnivorous minnows, prevents propagation of our most serious mosquito pests along the coast. In the interior swamps also, a similar situation prevails and the stockings of all waters with a healthy association of aquatic life which includes Gambusia minnows, prohibits malaria mosquitos from breeding in the flooded areas. It may not be generally known that our river swamps, where regularly flooded, are free from malarial mosquitoes, and our lowest regions are free from malaria fever.

## FLOOD CONTROL

We do not desire to discuss the engineering aspects of flood control but are in favor, as far as they are shown to be practical by competent engineers, of a combination of all desirable methods of control, from checking inflow at the sources by reforestation, the terracing of farm lands on hilly or mountainous water sheds and the creation of artificial lakes and power projects, to bigger and better levees where needed, and relief outlets where desirable. Of the many methods of stream control which have been suggested from time to time, a summary of those ideas which have virtue in connection with the subject matter presented in this paper, with a few added comments will be presented.

### STREAM CONTROL AT THE HEAD-WATERS.

The most frequently suggested methods of flood control at the head-waters of streams, are by the preservation of existing forests and reforestation on water sheds and in stream valleys, these being strongly advocated by such men as Col. W. B.

Greeley, Chief of the U. S. Forest Service, and Charles Lathrop Pack, President of the American Tree Association. This will tend to equalize the run off because of the absorbent action of the humus on the forest floor, thus benefiting the fisheries of the smaller streams. It will also favor a more steady input of organic matter and food organisms from outside sources, thus creating a more balanced biological cycle between the fish and their outside sources of food, which latter are much richer in forest covered than in barren land or gullied hillsides. The preservation of forests and reforestation of interior swamp lands would also be a decided benefit to the fisheries of the interior in that these areas are the natural spawning grounds and refuge places for young fish of most species in inhabiting the Mississippi system.

The farmer as well as the forester can also be of help to our interior fisheries at the same time helping himself and helping to prevent floods. Deep ploughing to encourage absorbtion of water, terracing or building contour checks and furrows on hill slopes, prevention of over grazing, and planting of grass on barren water sheds suitable for grazing are among methods suggested. The building of obstructions with brush or wood work in gullies to prevent erosion, the erection of dams to provide ponds or impounding basins on farms, and the damming of small tributaries to create or to preserve lakes or swamps by individual farmers throughout the entire valley would in the aggegate not only help to minimize floods by aiding in the prevention of extreme fluctuations and thus assuring a more steady supply of water in the lower valley, but will materially benefit the fisheries nearer the sources of the streams. As it is now, in the lower valley, there is a shortage and high prices causing over fishing during the drouth periods, while there is an overproduction and consequent low prices just after the floods.

The benefits of stream control at the head-waters and their manifold interrelationships are too many to discuss in their fullness here. The results of such conservation of water supply at the sources, both in surface reservoirs and by maintenance of higher water tables thus creating vastly greater underground reservoirs, are only too obvious. The checking of soil erosion from farms and forests, preventing soil from muddying or clogging streams, will of course be a decided benefit to the fish and other aquatic life. By holding the water back so that there is more percolation and thus a greater flow in the drouth periods and so that the valley soil is kept damp and the swamps wet, the streams and their valleys become ef-

fective fire lines instead of fire hazards. The fire prevention thus afforded, helps to prevent "alkali poisoning" of streams or lakes by the accumulation therein of potash and other salts which are the residue of forest fires.

The general benefit to our fisheries from flood control at the sources of streams will be due then to a minimizing of the alternate disastrous effects of severe drouths and floods, a reduction of serious natural and artificial pollution, the maintenance of a more abundant and constant food supply, and the creation of natural fish hatcheries and refuge places for young fish along the smaller streams where they are most needed.

The individual farmer will be amply repaid for his efforts by holding his soil or soil fertility, for rapid run off carries the top soil with its most valuable element, the humus, away, instead of the water being absorbed and slowly filtering into the ground, H. H. Bennett of the Bureau of Soils, U. S. Department of Agriculture, estimates that the soil elements lost annually by lack of soil conservation to be worth two billion dollars. Is it a wonder then that we have an over production of fish in Louisiana waters after every flood? To quote Mr. Bennett, "Terrace all slopes of tilled land, put the steeper slopes and inferior soil types in grass and timber, and we will speedily have a situation that will not only serve as a mighty prop to the effectiveness of levees and reservoirs, but one that will lessen the economic ills of countless farmers." The farmer will also benefit by a supplemental food supply in the way of fish, frogs, turtes and game, as well as a fur crop to tide him over the winter idle period, to say nothing of the newly created sport and means of healthful outdoor recreation.

### STREAM CONTROL ON THE LARGER TRIBUTARIES

The building of large impounding reservoirs upon the larger tributaries of the Mississippi as a means of flood control supplemental to our present levee system, finds its greatest argument in the need for water power and water for irrigation. From the standpoint of the farmer and the fisheries the benefits will be similar but greater in proportion as the storage capacity of these projects is greater than in the smaller projects. The fish of the Mississippi Valley not being migratory to any great extent, are all of the type that thrive in lakes, and fish production of such impounding basins will be of no little importance. Several such lakes in Louisiana, having a constant level maintained by a dam, Caddo Lake near Shreveport being the largest, are among the greatest inland fishing

resorts in the country, and demonstrate amply that a constant water supply means a constant source of fish as food and for recreation, this aside from the benefits to the other wild life, to the farm, and the attraction of a valuable tourist crop of no small proportions.

### STREAM CONTROL BY RELIEF OUTLETS.

Since the Mississippi River itself is demanding relief outlets and since along the lower river our immediate concern is relief, a discussion of flood control by means of levees and relief outlets in their relation to fisheries should be our chief concern in this paper.

From the phenomenal increases in the fish life of the lower valley during every flood, so pronounced during the 1927 disaster, there is one important lesson we must learn. Those wet lands are in reality acting as reservoirs for the reception of organic matter which is washed by rainfall from the land areas. In sections of the country where there are no marshes, lakes, and bays, most of the richest elements of the soil are lost into the streams and eventually reach the sea where they fertilize waters inaccessible to the great bulk of the American population. Not so in our region where these wet areas serve as a check and there is a constant return of this organic matter, with interest, to the soil. The droppings of water birds and mammals, which feed upon fish or other aquatic creatures as well as the bodies of those which happen to die on land form a rich source of fertilizer. Many reptiles and amphibians which feed on aquatic organisms, are also an important source of fertilizer elements, this being particularly significant in the case of certain frogs and toads which live on organic matter in the water when tadpoles, but come out upon land after transformation to leave their droppings or dead bodies to become valuable ingredients of the soil. Among other aquatic creatures the insects play an important part in the restoration of the soil, for these live as larvae in the water and during their nuptial flights come upon the land in great swarms, where the majority die through accident or are eaten by land creatures, in either case eventually adding fertilizer to the soil.

Is there any wonder that our low level alluvial lands need no artificial fertilization? The secret has been discovered in the adjacent wet lands which are not only valuable then for their great diversity of natural resources, but because they return to our agricultural lands the richness which rightly be-

longs to them, making such agricultural lands the richest in the world. There is such a thing as carrying flood protection too far in one direction, and, if we continue to pursue a policy of levees only, combined with excessive drainage, our higher level alluvial lands in the interior of the state will soon lose their greatest value for agricultural purposes, because the interchange of organic elements between the land and water areas cannot continue when all the swamps are drained.

A proper system of levees and back levees, designed for the purpose of protecting the more valuable front lands along the rims of the great lowland basins, combined with relief outlets into those basins which should be dedicated to the floods, would restore much of our formerly wet areas to their primitive condition. This would result in a rehabilitation of these regions by their native wild fauna, a fauna so rich that during 1925, immediately after our most disastrous drouth, it produced a gathered crop valued in the raw state at some fifteen million dollars.

In some instances, such flood protection will complicate our drainage problems, requiring the use of pumping plants during the high water periods, but in other instances, especially where sea levels can be maintained, this problem actually can be simplified by proper location of levees. The details of drainage must be left to the engineers, but there is one aspect of drainage which should be discussed here. Just as the floods result in enrichment of the soil by the deposition of organic matter and certain minerals therein, so conversely drainage results in a loss of these valuable elements causing impoverishment of the soil. Therefore, the rich alluvial lands, deprived not only of their periodic flood-born enrichment, but actually made still poorer by drainage, must be artifically restored. This can be done by ordinary methods of fertilizing the soil, but might we not take the hint from the flood, so amply borne out also in rice irrigation in Louisiana, and resort to irrigation of other crops besides rice, not only to furnish adequate water to our crops during drouth periods which have now become exaggerated by drainage, but to restore the missing elements to the soil. River water, bayou water and swamp water are all rich in the needed elements and one or the other will be easily accessible in all of our alluvial lands if the flood control plan suggested herein is properly carried out.

The enrichment of adjacent farm lands will in turn react on our fisheries since a steady supply of insects and other terrestrial organisms will act as a constant source of food to the

fishes of the adjacent streams, whereas under present conditions during every drouth the amount of insect and other terrestrial life entering the waters becomes so small that our fish suffer greatly as a consequence.

As a result of a study of the effects of crevasses, coupled with studies of the natural passes at the mouth of the Mississippi, we have come to the conclusion, that from the standpoint of all our fisheries resources, properly constructed spillways, designed to utilize the great lowland basins in the lower valley, would be decidedly beneficial and would increase our fisheries wealth manifold.

It must be understood that a crevasse in reality results in the restoration of our wet lands to a primitive virgin condition, such as always existed before the days of levees, and still exists below the termination of the levee line near the mouth of the Mississippi. There is no habitat anywhere in the United States in which fresh water fish population, both game and commercial species, is as dense as in the lagoons and smaller passes in the marshes near the mouth of the river or in similar areas created by crevasses. This is due to the vast amount of plant and animal nutriment carried in the water. On account of the current and muddy water, most aquatic plants cannot grow in the Mississippi River, but as soon as the current slackens and the silt settles out, all kinds of fresh water vegetation thrive, the species depending largely upon the depth of the water, and the exceedingly rich aquatic fauna previously described develops as a consequence.

The effect of a crevasse is akin to cultivation and fertilization of farm lands and might be termed wholesale aquiculture. Since many of the larger aquatic organisms take from one to several years to reach maturity, the beneficial effects of permanent spillways would be cumulative, and the commercial value of those resources depending upon such water for their existence would be increased manifold.

The marine life of Louisiana differs fundamentally from that of the adjacent gulf states largely because of its ready adaptation to the temporary conditions produced annually by the Mississippi at flood time and the large majority of our valuable marine species thrive on floods. Such valuable forms as our shrimp, crabs, croakers and mullet and some others spawn at sea, or in sea water, but the young enter fresh or brackish water where they thrive and grow faster, free from their enemies and diseases. It is a well known fact that the oyster thrives in a mixture of fresh and salt water and fresh

water kills off their natural enemies. Shallow fresh water upon reaching the sea floats upon the salt water as it continues its seaward flow, while the sea tide rises and falls as usual beneath the fresh water. It is mainly for that reason that river water, when in a shallow sheet, is not as destructive to oysters and other fisheries as might be expected, and often while the surface water is fresh enough to drink, the oysters beneath are still salty and palatable.

As to the manner of construction of spillways that will increase instead of reduce the annual crop of fish and wild life, there is one matter of considerable importance to be considered. Such waters, after passing through the levees and beyond the Mississippi ridge, must be spread out over a wide area just as it is taking place in the flooded regions this year. The same volume of water shunted between levees, would do irreparable harm to our oyster reefs on the coast, burying many beds under tons of mud which will not have had a chance to be deposited earlier, while over even greater areas the oysters would be killed by prolonged exposure to excessive volumes of fresh water, which would not flow out in a sheet over the surface of the salt water as it does when spread out, but would act as a mass flowing one way, then another, depending on the winds and tides. Such streams might also prove undesirable by creating engineering difficulties of their own, at the same time not producing the benefits of a large expanse of fresh water of shallow depth spread over a large area of marsh or swamp lands.

While not attempting to encroach upon the engineering aspects of the problem, it would seem that a protection levee south of the St. Bernard Ridge at or near the marsh line and another east of the Mississippi Ridge at the marsh line, extending south to Point-ala-Hache would best serve the biological requirements of a spillway below New Orleans. The canals should lie on the ridge side of the levee so that the needs of drainage and irrigation might be served, yet without permitting the encroachmetns of salt water during times of drouth, which are ruinous to agriculture and cattle raising, as well as bring about the periodic mosquito plagues which make life unbearable and drive industry away from the lower parishes.

A spillway likewise has been proposed for the east bank above New Orleans. From the fisheries standpoint, that suggested near Burnside would be the most beneficial, because the waters could be spread out in a large shallow sheet in the extensive swamps of that section before they enter Lakes Maure-

pas and Pontchartrain. A great fresh water fishery, both game and commercial, now easily reached by highways would be perpetuated thereby, whereas if confined between levees and shunted into the lakes much harm might be done, while the benefits to accrue would not be as great. On the west side of the river, any spillway plans should include the use of the entire Atchafalaya and Tensas basins, except the higher level rims of these basins, if the benefits to our fisheries described in this paper are desired.

## CONCLUSION

In view of the millions of idle acres of farm lands in this state today and the continued surplus production of our major crops, and after considering on the other hand, the almost insatiable demand for fisheries and their products in the interior states, the best use to which we could put our great lowland basins today would be to dedicate them to the floods, fish and higher aquatic wild life. The construction of proper spillways making use of these great basins would be the greatest move in fish conservation this country has ever made. Since the larger aquatic organisms take several years to reach maturity, if spillways on the Mississippi were permanently located, their benefiical effects would be cumulative and the value of our fisheries could be increased manifold thereby, and more than pay the bill for flood control. Since public hunting and trapping grounds are fast becoming a thing of the past, we could maintain forever in Louisiana for public use, the finest hunting, fishing and trapping grounds in the world, always easily accessible to the population of a large metropolitan district and a dense rural population, as well as being an attractive virgin territory available to sportsmen and naturalists of the entire country and possessing an intrinsic beauty so unique as to be a drawing card for tourists from everywhere.

There would be several other decided benefits brought about by regular flooding of our great lowland basins, among them moderation of climate, better health conditions and more productive farm lands, the latter due to the maintenance of a higher ground water level for growing crops, and proximity of water for irrigation of adjacent agricultural lands in time of drouth, which water in itself is sufficiently rich in fertilizer elements to make other artificial fertilization unnecessary.

With these valued uses, added to the fact that they will be continually growing valuable forests at the same time, while

always acting as flood insurance for the industrial centers and agricultural regions, the term waste lands applied by the ignorant to these great areas, would no longer have the slightest grounds for justification.

Our main hope now is that national patriotism will overpower sectionalism, and that partisan politics will not prevent Louisiana from overcoming her main drawback, the ever-present menace of floods, at the same time assuring her rightful place in providing for the nation a wealth of aquatic natural resources such as cannot be approached by any other region of the country, thus converting our flood regions into great revenue producers at all times.

### *Discussion*

Supplementing his paper, Mr. Viosca said:

The fisheries of Louisiana differ from those of the other gulf states in that our fish are particularly adapted to mud bottom waters and are capable of migrating into fresh water. Practically all our salt water fish, even those that breed away out in the gulf, can migrate into fresh water, into sea level lakes; and some of them even ascend in above sea level.

Our Board of Health made an investigation of the effect of the floods on the oyster crop, and they found that every second sample showed a high salt content, and every alternate sample a low salt content. I inquired whether they took every second sample on the bottom, and they said yes. Every second sample showed pure sea water. I said: "Don't you know that fresh water floats on sea water?" The tide rises under the fresh water which flows out in a thin sheet. If this water was run out between two levees it would go out in a mass and, depending on which way the tide would turn, it would periodically kill the oysters by flowing out all the water to the bottom. Only a small percentage of our oyster reefs, approximately one-fifth, were actually killed by the present flood, because the water goes out in a thin sheet, usually not more than a foot deep, and under that is the sea water.

Mr. Avery: One point made by Mr. Viosca, while perhaps it has no bearing on the question of the fisheries is interesting, to my mind, with reference to the whole subject of flood control. Perhaps many of you read recently an article by a prominent writer in a publication of wide circulation in which it was argued that the flooding of the lands of the delta region of the Mississippi was not beneficial to agriculture because it came at the time of year when it would destroy the crops, whereas in the delta of the Nile, where we are accustomed to regard the floods as beneficial, it comes at the time of year when it is not injurious to agricul-

tural interests, but, on the contrary is beneficial. I would like to hear what Mr. Viosca has to say on that phase of the subject.

MR. VIOSCA: If I were a farmer in Southern Louisiana I would raise one crop the year following every flood, and make more money than by continuing year in and year out, because the fertilizer in the higher level lands disappears in the course of a few years, and you have to pay a lot of money for fertilizer, which correspondingly reduces your profits. In the year following a flood you can start with land as clear as this floor, rich in fertilizing elements, and you can make more money off that crop than you can the rest of the time. But unfortunately in the case of some of our floods, as in this one, the flooding is too late in the year. Some of our floods come down early in February and March, and we can plant after the floods and make good crops. This year I think we shall still produce enough sugar cane, corn and cotton, because we have been complaining in the past of surplus crops, and the more the government complains of surplus crops the more crops the farmers plant, because they think the other fellows are not going to plant. So they are making less money out of farming every year because of surplus crops. But the flooding is actually reducing the farm lands to where they ought to be so that the farmers can make a profit. Next year the farmers will be able to make money without any fertilizers, and this year they can make a lot of money on fish; they do not need to go farming anyhow.

MR. GEORGE W. FIELD (Massachusetts): I think it would be desirable that this association should adopt a resolution urging engineers to tie up more closely with the biologists in dealing with these problems. Hitherto engineers have been inclined to go ahead and build sewers, levees, and various other engineering projects without reference to the biological factor. In this particular case there is almost no parallel with the Nile, although there is no question that a method can be worked out for the utilization of this surplus water at any season of the year when it can be used most advantageously for raising fish in Louisiana and for raising birds and fish in Minnesota and Wisconsin. It is an engineering problem which should be tied up with the biological aspects of the whole matter.

MR. LECOMPTE: I would like to ask Mr. Viosca what effect this 1927 flood had on the muskrat industry of Louisiana.

MR. VIOSCA: I think it is going to be decidedly beneficial. In about 1924, I think it was, we went through the most disastrous drouth in the history of the state, and that section of the state that was flooded by the break twelve miles below New Orleans in 1922 produced fifty per cent of the muskrats of the entire state of Louisiana. The coastal plain section produced no muskrats; the only ones produced in that year were at the mouth of the Atchafalaya River near the mouth of the Mississippi and in the section where the 1922 crevasse broke out two years pre-

viously. There was some loss of muskrats which was spectacular, but that was in an area just a few square miles in extent right where the waters actually flowed down several feet deep. I do not expect any decrease in the muskrat crop this year except in the zones that were immediately affected.

MR. LECOMPTE: Isn't that a large zone, however? Didn't it cover a large territory?

MR. VIOSCA: It affected a zone which included our best muskrat territory during the disastrous drouth period, but what has happened there? Thin sheets of water are rehabilitating sections of the state to a much greater extent, sections in which muskrats could not live on account of the salt water; they just moved over into a better area. When you get down to the coast the drainage of bayous which follow the passage of the Mississippi is amply sufficient to take care of the water which comes through these crevasses. Some twenty odd miles from the artificial opening in the river below New Orleans the land area is entirely out at low tide and only flooded at high tide. In other words, for a distance of twenty miles the water which is flowing some twenty feet above the high land level is dropped down below sea level and is taken off by natural channels.

MR. ADAMS: In this newly created breeding ground for muskrats, have you got a sufficient stock to properly stock it?

MR. VIOSCA: The past history of the crevasses seems to show that we have.

MR. ADAMS: In an article on the muskrat situation in Louisiana, Mr. Stanley Clisby Arthur, of your Wild Life Division, seems to paint entirely different picture from what you do. I understood from his article that the muskrats had been very greatly depleted by this flood, due to the lack of food, and also due to the effect of the sun.

MR. VIOSCA: He is talking of that area which was immediately affected by the dynamiting of the levee. I think nearly two thousand feet of levee were blown out, the water poured through there, and the muskrats had to climb trees in an effort to save themselves. But he and I made a joint investigation of the oyster lands, and we came to the same conclusions.

MR. ADAMS: Any of the commissioners who have not read the last biennial reports of the State of Louisiana, in which they deal more exhaustively with the muskrats than I believe has ever been done before, should by all means get that report and study it. It is a most extraordinary treatment of the muskrat problem.

MR. VIOSCA: We would be glad to send it to anybody who wants it.

MR. LECOMPTE: We have the same conditions in Maryland in the muskrat section—the flooding of our marshes by salt water, caused by extreme high tides. Of course we do not have what we term a flood

area, but we do have, with the extreme southwest and southeast winds which prevail for two or three days at times, extreme tides which overflow the marshes and of course leave the salt settling into the marsh grasses. That is very detrimental to the muskrats, which must have fresh water. During the season of 1925 we had an extreme drouth during the whole summer, continuing from about the first of April until September, and our muskrats were practically eliminated in a good many sections on account of there being no water. They suffer as much, or more, with us from lack of water as they do from over-flooding, because they require water to build their homes to live in; and they require water also to produce the aquatic roots on which they live. Your muskrats in Louisiana propagate, I should think, in February, whereas ours propagate in March: our first young will be seen about the fifteenth of March to the first of April. And this flood which hit your state—was it in May, or the last of April?

MR. VIOSCA: April.

MR. LECOMPTE: Well, your muskrats were then from four to six weeks of age. I imagine that in the immediate territory which was flooded the young, and also the breeders, did suffer considerably. But as I understand Mr. Viosca's statement, whereas it did destroy in that immediate section where the flood occurred, it benefited the surrounding territories by flooding them with fresh water.

MR. VIOSCA: For each area that was adversely affected there was ten times that much water area created, and the muskrats simply migrated for a few miles.

# PROGRESS OF THE BIOLOGICAL SURVEY IN NEW YORK STATE

EMMELINE MOORE.

*N. Y. State Conservation Dept.*

In my paper before this society last year reference was made to present tendencies in the several states to emphasize stream and lake surveys and the importance that attaches thereto in developing a more intelligent stocking policy. Already two reports of this kind have come from the press during the past year—one from the Commonwealth of Pennsylvania entitled "A Survey of the Streams, Lakes and Ponds in Susquehanna County" and the other from New York State bearing the title "A Biological Survey of the Genesee River System"; the latter supplemental to the Sixteenth Annual Report of the Conservation Department. Both reports are the first of a series intended to cover eventually the entire areas of the respective states.

In New York State it serves our purpose best to pursue the surveys by watersheds. This plan is adopted because of the nature of certain major problems impinging upon that of a stocking policy, such as, pollution, basic problems in fish population and distribution, the impounding of waters in hydroelectric development, municipal water supplies, the influence of canals, problems in commercial fishing and the like—in all of which greater continuity and comprehensiveness is attained by attacking the watershed as a unit.

Last year for a start we selected the Genesee watershed, a relatively simple problem of a drainage basin covering a fertile valley of open, agricultural lands, and generally denuded hill country. The report of this survey is now being distributed. The survey now going on this season covers the Oswego drainage system, the second largest watershed in the state and the spreading over portions of a dozen counties.

While in general the plan of last year is being followed, the scope of the work is more extensive and offers interesting complexities in organization. Moreover, nature does not repeat herself even in watersheds, and this is offered in further justification for presenting another paper on our state survey.

Within the coverage of the Oswego watershed—including an area of 5,002 square miles—lie the seven Finger Lakes, all long, narrow, very deep lakes with generally steep slopes, little standing vegetation and with varying reputation as to productivity. The other large lake in the watershed is Oneida,

a relatively shallow lake very productive and a stronghold for carp. Besides there are numerous small lakes and ponds, a vast assemblage of inlet tributaries and three fair sized rivers, the largest, the Oswego, unites all of the outlets and carries the drainage into Lake Ontario.

The survey is being conducted along three main lines—stream survey, lake survey, and carp control studies, the last named centering in Lake Oneida. Each of the main divisions is further classified with work progressing as follows:

In the stream survey, Dr. Embody and eight associates are studying the streams, using such field blanks as are shown here for assembling data directly related to the stocking policy; the ichthyologist, Mr. J. R. Greeley, and three assistants are collecting specimens of all species of fish in the watershed; two biologists are working on a research problem which will throw light on the quantity of food available in streams of a given type.

In the lake studies which are under the immediate direction of Dr. Eaton, attention is focussed upon the problems related to productivity. His unit consisting of five associates and two practical fishermen is studying the conditions of the deep lake bottoms, the inhabitants of the lake, their food staples and their abundance, temperatures, gaseous relations, etc. A unit of four is studying the plankton of the lakes and problems related to plant distribution. Both lakes and streams come under the scrutiny of the chemists who are studying pollution and who will depict in graphic form conditions of pollution in the watershed. An artist is reproducing in color some of the important species of fish adding to the collection begun last year and looking toward a proposed illustrated volume on the Fishes of New York State.

Carp control studies on Lake Oneida comprise two lines of work—the scientific study of the problem combined with carp seining activities. The plan of the work is based on the proposition that carp control is a scientific problem and as such is more than a seining industry to keep the numbers down, as effectual as that is. A professional carp seiner with men under his employ has the concession for carp seining and regular hauls are made in deep and in shallow water. Working in close conjunction with this unit is a corps of six scientists who are studying various problems related to the presence and abundance of carp on the lake, giving attention to such problems as statistics on age, weight and growth; their number and migrations about the lake; interference with spawning ac-

tivities of other fish and with vegetation; the study of the young; and so on. These studies are of great interest to us because this lake stands predominantly among the larger lakes as one of the most productive of food and game fish.

All these activities are bringing forth a wealth of facts which are being linked up on the problems at hand.

The personnel of specialists and assistants engaged in this large enterprise numbers 44. There are biologists, fish culturists, zoologists, ichthyologists, botanists, chemists, a planktonologist, an artist, a map maker, a curator, graduate students, laborers, and carp seiners. Besides there is a guest specialist, Prof. S. H. Gage of Cornell, an authority on the lamprey. Prof. Gage has consented to bring together for our final report the results of a life-long study of the lamprey, emphasizing in his paper both the life history and economics of this serious pest of our lake fishes.

The period in the field is three months, from June 15 to September 15. The appropriation of $50,000 for the work is drawn from the Conservation Fund, a fund accruing from fish and game licenses.

Five educational institutions in the state are cooperating with the Conservation Department. They are Syracuse and Cornell Universities, Hobart College, Rensselaer Polytechnic Institute and the State Normal College. The nucleus of the staff this year was derived from the survey unit of last year with nearly all in the field again this year.

The preparations for carrying out this larger project were about as follows: The proposed program of the Conservation Department was placed in agenda form before a conference of scientists representing the cooperating institutions, the Conservation Commissioner presiding. The presence of more than one institution in the field made essential the adoption of general guiding principles governing action between the department and the outside agencies. This should enable both the Conservation Department and the institution concerned to progress through long-time and continuous association. At this conference also the main objectives to be sought in the present survey were discussed and emphasized; problems were assigned to the different units; and equipment and time schedules were considered.

The benefits derived from these surveys have become apparent in several directions: The stocking maps serve as a guide in the apportionment of fish by eliminating streams unfit to receive them and stocking more heavily where conditions

permit. Facts are linked up so that they afford a basis for fisheries legislation and serve as a guide in placing research on the weak spots in our conservation program; the graphic representation of pollutional conditions provides localities and organizations with a concrete picture of conditions within their respective communities; and last but not least the surveys afford a training school for greater efficiency in the field of the fisheries, and is in this respect a contribution to the future personnel.

*Discussion.*

MR. ADAMS: I would like to ask Dr. Moore whether in the preliminary part of this survey a study was made to see whether or not the changes arising out of what, for the sake of a better term, we might call civilization in any one of these survey regions will likely in the future cause such a complete reversal of conditions as to render these surveys more or less obsolete in a comparatively short time.

DR. EMMELINE MOORE: Do you refer to large projects like hydro-electric projects?

MR. ADAMS: Yes, and the taking of water areas for municipal water supply purposes; the deforestation of tracts over which the state, for example, has no control, and so on, world without end.

DR. EMMELINE MOORE: In our survey of last year that question came up. In the Genesee River watershed two lakes out of the four are preempted by Rochester for its municipal water supply, and there was an indication that the third or fourth might be used for the same purpose, so that we practically kept our hands off those particular water areas.

MR. ADAMS: What I mean is this: Taking the second region that you refer to; you have the impression that in the next say twenty-five years there will not be so many fundamental changes wrought there by man as practically to destroy the work you are now doing?

DR. EMMELINE MOORE: Of course we cannot foresee just what is going to happen. Some of the lakes already are tapped for water supply. For instance Skaneateles is used by Syracuse; Seneca Lake by Geneva, and Auburn draws on Owasco. You see, the water supplies there are so stupendous that just that phase of the problem would not change the picture.

MR. ADAMS: Then you have this advantage: you have this permanent data, and it would be only a simple matter to modify it from time to time.

DR. EMMELINE MOORE: Yes. Of course, this survey covering so many water sheds—nineteen—we hope to finish in nineteen years. We took one last year as a start—a small one—and this year we are covering three times the ground and I think we are covering it very much better. Another season we might cover these three that are smaller, so we would

hope to reduce the number of years we put in these watershed surveys—which must be regarded in the way of a preliminary survey, on which we throw back the research problems and the various questions that come up—economic problems, purely scientific problems. It is practically a bird's-eye view of the situation, bringing out the weak spots in our conservation program.

MR. M. S. JOHNSON (Minnesota): Do your investigations of the carp so far indicate that it is a valuable fish, or otherwise?

DR. EMMELINE MOORE: We are not trying to prove that it is a valuable fish, but our investigations have brought out some very interesting phases. The distribution of carp in the Finger Lakes is largely concentrated in Lake Oneida and in the shallower portions of the Finger Lakes where the vegetation is dense.

MR. JOHN R. GREELEY (New York): There are carp in all the Finger Lakes, but of course they are not adapted to deep water life.

MR. BULLER: We are doing work along these lines in Pennsylvania, though not as elaborately as you are going into it. We believe it will be of great value to us in enabling us to stock our streams with what is suitable to them. If there is any abatement of pollution in a given stream we will have a knowledge of it; we will check up on it and keep the records in that way. If there is any increased pollution we will also have that—and I take it you will do the same thing.

DR. EMMELINE MOORE: We trust so.

MR. BULLER: I deem it a very great thing, a very important work, because it gives us a chance to map out a more intelligent program when we come to stock that stream; it enables us to know whether there is food in it for the fish we propose to plant there. We are also trying to create food in all these streams at the same time.

MR. ADAMS: I did not mean, in asking the question, to arouse any distrust as to the value of the work; it was just a practical question of readjustment. I think it behooves all of us in the several states to get behind the states which are doing this splendid work, to give them our moral support and to further their work wherever we can.

DR. R. V. BANGHAM (Wooster, Ohio): I wish other states would do the same thing in this survey work; it is giving us an extremely valuable method of working at these problems. May I ask what work is being done with regard to parasites in the streams?

DR. EMMELINE MOORE: While the work on parasitism in the field survey is not as well organized as it should be, we have been making collections of bass that are parasitized with the flatworm; and there is of course the lamprey parasitism, which is a serious one.

DR. BANGHAM: With regard to the flatworm parasite, what correlation do you find as between river and lake drainage? We find it almost entirely in lake drainage.

DR. EMMELINE MOORE: The Genesee survey showed that in the specimens from Lake Hemlock and, I think, some others—I do not remember now just which lakes—there was excessive parasitism compared to the streams. There was very little stream parasitism at that time.

MR. LECOMPTE: For the past ten years I have tried to impress our commission with the necessity for a survey of the streams of the state, not particularly from the scientific point of view, but having in mind the fact that it is money thrown away to continue planting fish in streams where the water will not take care of them. Commissioner Earle came into office in 1924 and decided to make a survey of the streams of the state, for which purpose he has employed Mr. Fred Treselt, formerly of the New Jersey Fish and Game Commission. We have been planting certain streams with fish, thinking we were doing the proper thing, meeting the demands of the public, yet we have found it useless to plant fish there because the streams would not support them. As a result of the last survey which was made, in Washington county, one of our mountainous districts, we have located trout streams that we did not know we had—that is, streams that are suitable for trout but in which we have been planting bass. Mr. Treselt says he has located some of the best trout streams in the state, in a county where we did not know that they existed. Every state should make a survey of streams and, no matter how urgent the requests may be or how much pressure is brought to bear on the commission, discontinue to plant fish in streams where a survey absolutely shows that it is impracticable.

DR. CARL L. HUBBS (Michigan): I would like to ask a question on this point: Are you sure that the fish are going to be planted in the streams that you recommend, and that they will not be planted in the streams that you blackball?

DR. EMMELINE MOORE: Of course that in itself requires a great deal of thought. This year, however, in the smaller survey, the plantings according to the program developed last year were exceeded. But we have received from the sportsmen's clubs splendid support in carrying out our recommendations—almost unusual support, I would say. The co-operation was fairly general; there were very few assaults from any quarter. We did have two or three rather interesting and refreshing assaults from people who wanted their own kind of fish that they had planted for years and years, but we aim to abide by the recommendations of the survey if it can possibly be done. Our organization, however, is still inadequate to permit the very best results in the program.

DR. HUBBS: Do you rely upon the sportsmen's organizations that actually handle the fish?

DR. EMMELINE MOORE: No; so far as possible the hatchery units assist in the proper planting. All the fish that went into the streams of Chautauqua county last year were planted by the hatchery forces of

the Chautauqua hatchery. That was just outside our survey region, but this year we have the Caledonia hatchery unit planting fish within the Genesee watershed, and one or two other hatchery units planting in their immediate region. So we are adopting the principle—of course it cannot be put into operation wholesale—of gradually having those familiar with the habits of the fish do the planting.

DR. HUBBS: We have the same problem, of course, wherever survey work is done. In Michigan we actually employ the hatchery men themselves as units in the survey work. We have had twelve crews of hatchery men engaged in stream survey work this summer, the final recommendation being made by the investigators themselves. We feel that in that way the hatchery men will come to realize the importance of the work.

It must be recognized that we are pioneering in this sort of work; the whole biological story cannot be learned all at once, and we ought to have some way of following up these recommendations, following up the planting program after it is made, to test out what happens. The whole thing is as yet a matter of experiment; in fact the only way to get at these things is through experiment. Are you planning some means of following this work up so that you will be able to determine what results are being obtained?

DR. EMMELINE MOORE: Yes, we are, but we are feeling our way. It is a very big problem to work out. At present I do not think it can be definitely stated just what line will be followed, but we are aiming to plant our own fish and then to throw back on each watershed the problems that will be continuous with the years.

DR. HUBBS: Another advantage in using our hatchery men in the investigation is the fact that they are right on the ground and can watch these streams from year to year. If they have been planting brown trout in a stream according to the recommendations for several years and they find that the brown trout are not doing well, they can soon see that that is a mistake and try something else.

DR. EMMELINE MOORE: We often make mistakes, but wherever we can we are going over the ground to see whether mistakes can be rectified.

MR. BULLER: Undoubtedly the undertaking is a very large one. We expect it will take us quite a number of years to make a thorough study of our streams in Pennsylvania, and we estimate it is going to cost us a million dollars to do it.

DR. EMMELINE MOORE: Well, it is worth a million.

MR. DEROCHER (Nashua): Do you supply fish to any private individuals in those sections to be planted?

DR. EMMELINE MOORE: Yes, that for so many years has been the practice that in a single year, or two or three, we cannot change the plan suddenly. It has to be developed gradually.

PRESIDENT TITCOMB: You do not mean to privately posted waters?

MR. DEROCHER: No, I mean public waters. How do you determine whether fish that are not suitable for certain waters are not being planted in those waters?

DR. EMMELINE MOORE: The people who make applications for fish are supplied with the maps and with the suggestions that are made by the survey. The stocking policy of this current year is being developed by Dr. Embody and his assistants, and perhaps he could give us some suggestions there. But we are giving publicity to these findings; the accompanying statements and maps indicate where the fish are to go, and what kinds are to be planted.

MR. DEROCHER: It is stated on the application what waters they are to go to?

DR. EMMELINE MOORE: Yes.

MR. DEROCHER: We have that same thing to contend with in New Hampshire, where they are putting species in waters that are entirely unsuited to them. I think it is a good idea to have the hatchery employees—perhaps the wardens of the state—do it, rather than let the individual plant promiscuously here and there.

DR. EMMELINE MOORE: I think it is one splendid feature of the survey that the individual who makes an application can study his map. Every stream is named; it has a number given by the survey units that are working on this matter, and the individual makes his application from that name which is given by the survey. That helps.

# A RAPID METHOD FOR THE EXAMINATION OF LAKES AND STREAMS

DAVID L. BELDING

*From the Evans Memorial and Boston University School of Medicine*

In 1925 a rapid survey of the lakes and streams of Litchfield County, Connecticut, was carried out under the direction of Mr. John W. Titcomb of the Connecticut Fish Commission. The novel method of conducting the survey and the volume of information obtained at a minimum cost warrant a description of methods and results.

In the limited period of three weeks 272 streams and 100 lakes, which formed part of the drainage systems of the Housatonic and Farmington Rivers were examined. In spite of the fact that the records represent an impressionistic rather than a thorough examination, the results demonstrate that satisfactory data, suitable as a basis for further investigation and for establishing a stocking policy can be collected in a relatively short time by a competent observer using automobile transportation and stenographic assistance.

## SURVEY METHODS

The country was traversed in a zig-zag fashion by automobile with the aid of U. S. Geological Survey maps. Two men were required, one to operate the automobile and to assist in obtaining the data, the other to make the necessary observations. Wherever a road crossed a stream, an observation station was numbered on the map, and a record of the natural conditions of the stream at this point was entered in a notebook under a corresponding number. Whenever possible supplementary records of the character of the stream between observation points were made. By combining the field notes at the various observation points a description of the natural condition of the stream could be obtained. Except for minor modification the nomenclature and procedures in Standard Methods for the Examination of Lakes and Streams (1) were followed in recording, arranging and filing the data. Thus the results of other investigations may be utilized for the interpretation of the statistics.

A record of each lake and stream was entered on a 11 x 8½ inch card bearing the printed form, the one for streams being given below. It was filed alphabetically

according to the name of the body of water with suitable cross indices. In this manner a summary of the value, recommendations for stocking and natural conditions may be noted at a glance and more detailed information obtained from the description, written on the back of the card. Additional information at any future time may be added or corrections may be made.

Geological survey maps were mounted on similar cards of the same size. The lakes and streams were named or numbered and the county, town, and watershed boundaries appropriately designated. Each body of water was given a map number as described in Standard Methods. Unnamed streams were classified as tributaries or feeders and were indicated by a number together with the name of the stream into which they flowed, e.g. T No. 3 Shepaug River would indicate the third unnamed tributary stream entering the Shepaug River. Brook trout waters were indicated in red, brown trout in brown, and coarse fish in green. Posted or private waters were marked in blue and polluted waters in purple. Thus a combination of red and blue would indicate waters suitable of brook trout in which public fishing was prohibited.

STREAM SURVEY

**Name,** Blackberry River.
**System,** Blackberry River

**Stocking**
- **Value** ........................A"
- **Brook Tr.** ................+
- **Brown Tr.**.................—
- **Coarse Fish** ..............—

**County,** Litchfield. **Township,** Norfolk and Canaan.

**Map,** Sheffield 1.22, 1.23; Sandisfield 2.21; Winsted 9.1.

**Information,** David L. Belding, August, 1925.

**Source,** South of Crissey Pond, Norfolk. **Outlet,** Housatonic River.

**Length (Miles),** 11½. **Width (ft.),** 15. **Depth (ft.),** ¼. **Type,** Meadow.

**Velocity,** 73 rapid. **Permanence of Flow,** Copious.

**Tributaries—Number** 5. **Miles,** 7 feeders = 5½ miles.

**Shade,** Scanty. **Food,** Moderate. **Vegetation,** Considerable.

**Temperature,** Water, 60; air 68.

**Water—Color,** White. **Turb.,** Clear. **Bottom,** Gravel and small stones. **Pools,** Numerous.

**Ponds and Dams,** One pond; one dam 8 ft., upper part, broken.

**Pollution,** None. **Posted,** No.

**Course,** See general description on back of card.

**Fish**—Brook trout, dace and suckers. Information uncertain as to introduction of brown trout.

**Remarks**—Excellent brook trout stream. Easy fly fishing.

The results of the stream survey for Litchfield County are summarized in the following table. The application of the collected data to the problem of stream valuation and stocking is of interest.

STREAMS OF LITCHFIELD COUNTY

| | Number | Miles |
|---|---|---|
| **General Statistics:** | | |
| Total | 272 | 1100 |
| Feeders | 1290 | 987 |
| Public | 192 | 919 |
| Private | 80 | 181 |
| Polluted | 16 | 55 |
| **Value:** | | |
| Class A | 50 | 265 |
| Class B | 84 | 323 |
| Class C | 71 | 281 |
| Class D | 60 | 203 |
| Unclassified | 7 | 28 |
| **Recommendations for Public Stocking:** | | |
| Brook Trout | 100 | 399 |
| Brown Trout | 41 | 204 |
| Coarse Fish | 8 | 119 |

## VALUATION

The value of the different streams is estimated according to their potential production of brook trout. The classification which is based upon the natural condition of the stream and upon present and past fish production depends upon the ability of the inspector to judge correctly the value of each stream. Four classes have been arbitrarily made: A, excellent brook trout water, B, fair, C, indifferent, and D, poor or unsatisfactory. Provided a stream is of sufficient size to be worthy of consideration the classification is made irrespective of size, although a medium grade large stream would probably receive a higher classification than a small stream of the same character.

Different sections of a stream may have different values, e.g. a stream 5 miles in length may be recorded as $A^3B^2$ indicating three miles of excellent brook trout water and two miles of fair. In addition on the record card a further notation indicates whether fishing is restricted, e.g. $A^3$ $(P^2)$ denotes three miles of excellent brook trout water, of which two miles are posted. The total number of streams for any class is obtained by adding the fractional parts of those streams which have been given more than one value. In

Litchfield County one-half of the streams and 54 per cent of the mileage fall in the A and B classes. The privately controlled streams show a higher proportion, namely 70 per cent.

## STOCKING

Beneath the value on the record card the species of fish recommended for the stream are entered. The species for Litchfield County comprise brook trout, brown trout and various coarse fish, such as bass, pike perch, yellow perch, pickerel, bullheads and blue gill sunfish. Since the streams are almost exclusively trout waters the coarse fish are restricted to a few large rivers. Stocking with brook trout is rarely recommended for other than A and B class streams, only one-quarter of the mileage of C class streams being judged worthy. Occasionally brook and brown trout are recommended for the same stream when natural or artificial barriers in the form of water falls and dams permit stocking with antagonistic species.

Embody (2) has formulated a table which indicates the number of 3 inch fingerling brook trout to be planted per mile in streams of various widths according to different food and pool conditions. Since the qualitative value per mile of stream, the width, prevalence of pools, and abundance of natural food were recorded according to Standard Methods, it is possible by means of Embody's table to determine the number of brook trout for planting per mile of stream.

## NATURAL CONDITIONS

The best brook trout streams of Litchfield County are of the upland-meadow type, which comprises forty per cent of the total number. The poorest streams are of the torrential mountain type, in which deforestation has increased the irregularity of flow. One-quarter of the streams, chiefly the mountain type, run dry during the late summer.

The presence of pools must be considered in determining stream value inasmuch as they increase the water area and provide favorable grounds for fish, especially in periods of drought. Dams influence stocking, prevent fish from ascending streams, and by forming ponds increase the water area. Shallow unsheltered ponds injure streams by producing an abnormally high water temperature. The temperature of a stream, although in a measure dependent up-

on volume, springs, and pools is chiefly influenced by shade. The amount of shade runs a close parallel with temperature and stream valuation. There is a striking similarity in the 62 per cent of streams considered worth stocking with brook trout on the basis of their natural conditions and the 70 per cent estimated as suitable by the use of Embody's correlation temperature table.

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### *Discussion.*

MR. ADAMS: What is the definition of a public stream in Connecticut?

PRESIDENT TITCOMB: I will answer that. Any stream that is open to the public is called a public stream. We have not any public waters.

MR. ADAMS: It may be public when this survey is made, and it may be private later on.

PRESIDENT TITCOMB: We have it covered by applications every year, in which they state whether it is posted or not.

MR. ADAMS: If the riparian owners elected to do so they could post those streams at any time?

PRESIDENT TITCOMB: Absolutely. You cannot take away a man's private trespass rights.

DR. BELDING: You keep closely in touch with changes, do you not, Mr. Titcomb?

PRESIDENT TITCOMB: Every year, yes.

MR. BULLER: I am very much interested in the talk given by Dr. Belding. We in Pennsylvania believe it is our bounden duty to maintain the fishing for our people, because you have a contented people when they have places to go for recreation, and when you have a contented people, you have good government. As you perhaps know, we have a Water and Power Resource Board in the State of Pennsylvania, of which I am a member, and which has authority over the construction of dams and bridges and encroachments on waters. There is also a Sanitary Water Board, which has authority over all questions pertaining to the pollution of waters. Of this board I am also a member. Many bodies of water have been created in the State of Pennsylvania. Our largest body of water in the state has been created by one of the

hydro-electric companies, covering an area of 6,748 acres, with a shore line of 55 miles. I recognized at that time that this was going to be a private fishing ground, and I offered a resolution before that board, and had it passed, that in the case of every permit granted by the Water and Power Resource Board for the impounding of waters for any except domestic purposes, the permittee would have to agree to allow the public to fish in those waters, under rules and regulations laid down by the Board of Fish Commissioners, the corporation and other persons involved. Now, that is the policy that we are carrying on in Pennsylvania, and as a result of that policy we are going to save to the fishermen many thousands of acres of water. The company who built the lake I speak of fought that very hard, but as a result of our policy of cooperation with the heads of these companies, other lakes in the state that were private have been thrown open under the same rule to the fishermen, besides twenty-seven miles of very fine streams that hitherto were private. The state itself has gone to a great deal of expense—and rightly so—in purchasing about five million acres of waste lands and waters, and we have before the voters this coming fall a bond issue of $25,000,000—and I believe it will be passed—for the purpose of buying up all the waste lands and waters in the State of Pennsylvania that are for sale.

Now, when you come to the matter of water supplies for domestic purposes the public should be prohibited, except when the time comes that the municipality chlorinates their water or filters it; then the public may enjoy the privilege of fishing in those waters, the same as they do in other waters, without injuring the health of the people. That is what we are discussing now, and we hope to bring it about.

Mr. Frederick C. Walcott (Connecticut): We have very much the same condition, on a smaller scale, here in Connecticut. On the Housatonic River there are already two steps, and a third is about to be put in. The first step is the Stevenson dam, which provides the largest body of fresh water in the state. The step going in now will be nearly twice that size, and there will perhaps be others, constituting substantial bodies of still waters. The question to be considered is to what extent the vegetation in these bodies of water will stand the drying out which occurs periodically through the drawing off of the water. At the Stevenson dam the water would probably be taken down six feet, and we feel it will seriously affect the vegetable growth on the shores, and probably the food of the fish. I would like to ask what Mr Buller's opinion is on that point.

Mr. Buller: I think it will to a certain extent. In Pennsylvania the Wallen Paupack proposition, a hydro electric dam created on the Wallen Paupack creek, is subject to fall and rise; it is about the only one in the state in connection with which that condition prevails. It is going to affect the shore line to a certain extent; nevertheless we believe

that it will constitute a great recreation and fishing ground if we keep it properly stocked with fish. No doubt it will interfere with the natural production of fish in that body of water, and also to some extent with the food, but there are many projects in the making now in Pennsylvania that will not be subject to that rise and fall. We have before us now a proposition in the northwestern part of the state known as the Pymatuming swamp dam, covering an area of 24,000 acres. That will never be a drain in the manner that the Wallen Paupack proposition will. The Wallen Paupack is a unique engineering proposition. No water will ever go over the crest of the dam, but it is carried through an aqueduct and pours over the turbines at a fall of 350 feet. It is so constructed that no matter how great the flow of water is, none of it will ever go over the crest of the dam.

MR. ADAMS: I would like to ask whether in Pennsylvania you have objection raised by the owners or these large areas to permitting the public to go on them because of the fire menace, and how that situation is dealt with.

MR. BULLER: We deal with it in this way. These waters will be open to everybody, under certain rules and regulations. Three officers patrol the Lake Wallen Paupack proposition every day, and those officers are paid by the corporation. They are fish wardens, but the corporation pays their salary, and they see that the rules and regulations are carried out. No boat will be permitted on that water except by permit. Anybody can get a permit for a row boat, sail boat or canoe. On the issue of such a permit the boat is given a number and the holder of that permit will be liable for the violation of any of the rules and regulations on that body of water. The fine is $100, no matter what the violation is. Motor boats are entirely prohibited, because we have come to the conclusion, in Pennsylvania, that on our small bodies of waters we cannot have both motor boats and fishing.

MR. VIOSCA: The State of Louisiana has been making a general survey of her streams, but the survey is even more general than that which Dr. Belding has reported here. It was made incidentally to studies of stream pollution and other matters that were the subject of special inquiry. But the investigations have been carried on now over a period of about eleven years, and by accumulating small facts here and there we have been getting a very general ecological classification of our streams. In some of the states, that kind of work can be done in connection with their other activities, even if they do not go into it as deeply as Dr. Belding has in his particular investigation.

In connection with public water supplies for domestic purposes in Louisiana, we permit fishing in all water supply lakes of that kind. But in our state all the water supplies are chlorinated, and we have rapid sand filters; there is no such thing as taking the water and using it in

the raw state. With these filters, of course, even if there was pollution, it would not be as dangerous, in my opinion, as the thousands of people you see on bathing beaches in this section of the country. We have no such thing as typhoid in the large cities of Louisiana, and very little in the country, and the proof is that in the city of New Orleans the water which is used there is polluted by two-thirds of the United States. Of course we filter and chlorinate it.

Dr. Belding mentioned the effect of small dams on trout. I do not know anything about trout; we have no trout streams in our state. But even though small dams may be unfavorable to trout streams, might they not benefit the trout in increasing the food supply and giving better sources of supply? What is your experience in this line?

Dr. Belding: The temperature change is too great. Of course if they were shaded ponds, it would be all right; but they are exposed in the open fields.

Dr. Emmeline Moore: I would like to express my great appreciation of the interpretation Dr. Belding has given to this survey in Litchfield county, and I am glad that three of us, Dr. Embody, Mr. Greeley and I, who are actively interested in our survey in New York State, have listened to his interpretation. It is a matter of satisfaction that the surveys in the different states, if well founded may be interpretable in terms of each other. I think that is a very great gain, and I am confident that we are going in the right direction when that can be done.

President Titcomb: Dr. Stillman has surveyed two of our counties. We have three counties completed, and it is a mighty good investment. We have found that we have stocked streams with trout which would not support trout. Some of you people do not perhaps appreciate the situation in a state where we either have trout streams or we have no fishing at all, or practically none. When a stream in this latitude gets to the point where the temperature is too high to support trout life, it is quite a problem to find any other fish which will stand the torrential conditions which prevail in those warmer waters. We have county wardens supporting the work of these surveys by reporting, incidentally to their travels, the water temperatures during hot weather. We have blank forms which they fill out as they cross a stream in the hot, dry weather, giving the air and water temperatures. We add these to our card records, and thus know after a time quite definitely what streams are really suitable for trout. Connecticut is fortunate in having an underground stratum of water which is a source of supply to these streams and keeps them more or less cool even during drouths.

Mr. Adams: There is a phase of this work that has not been emphasized, and it relates to the reclamation of former reservoirs. In the New England States, and I think throughout the whole of the United

States, there is a vast acreage of abandoned power sites that it would be possible to buy. If this land that was formerly flooded could be thus acquired, a great many dams could be restored at comparatively small cost and we could acquire permanent public fishing grounds over which the state would have absolute control. In these particular bodies of water the state could make demonstrations of what can be done by more rigid rules and regulations than are applicable under existing laws to most of our bodies of water by the elimination of winter fishing, the making of soundings in those areas, the setting aside of the natural breeding areas; the limiting of catch more rigorously than is the case in most open water—in fine, making a demonstration of what can be done by careful nursing of all the resources of a given pond.

Mr. J. B. Doze: Our state is a plains state, sloping from four thousand feet in the northwest corner to about seven hundred feet in the southeast corner. We have three main drainage systems, the Kaw or Kansas and Arkansas rivers and the Cimarron. There is very little geological impression on the state in the way of glacial formation; in other words, the ice field did not reach Kansas except in the extreme northern part, and as a result we have no natural bodies of water. Practically every body of water we have has been created by erosion, or sand drift, or damming. The water area of the state has decreased from about 370 odd square miles to approximately 200. In order to meet that situation we created a commission known as the Forestry, Fish and Game Commission—forestry was attached to that commission in order to enable us to do some forestation. Last year we secured from the Legislature a fishing license. We sold it to the sportsman on the theory that we would take the money received from those licenses and establish public fishing grounds. Our revenue has jumped from $70,000 five years ago to approximately $225,000. We are in the course of constructing six lakes one of which will be 880 acres in area; the smallest will be something like 100 acres. We are spending for these purposes the money we are taking from our fishing and hunting licenses. We are offering our hunters an opportunity to have public shooting grounds in the time to come; and we are offering our fishermen public fishing grounds. When you realize that we have no public fishing outside of the coarser cat fishes, and that famous fish, the spotted channel cat—which to my mind is one of the finest fishes that swims—you can appreciate our problem. We have not taken over any present water areas; it has been the policy of the commission to create more water areas. If you are going to undertake a campaign of water impounding you should build lakes where none exist and leave as they are those that you have. You may, of course, take those over afterwards, but the pressing need undoubtedly is to create additional water areas.

Along with that proposition of creating public fishing grounds, migratory bird refuges and public shooting grounds—we have not arrived at

the public shooting grounds yet, and we will not for a few years—we have bought a large area of land around lakes. For instance, we bought a tract in Scott county in the extreme western part of the state, comprising 1,280 acres—and I want to tell you a little about that proposition. In this particular location known as Ladder Creek Canyon the Indians have a pueblo the known history of which dates back to 1620. There is a flow of spring water from the hills above that, amounting to a little over one thousand gallons a minute, and we propose putting a number of lakes in there and turning that over and making it not only a public fishing ground and a place for migratory birds, but also a state park. We are including in it this historic site; we are fencing the old pueblo, which is now all ruins, and we are leading these springs around to make different ponds. It is a long job; it will take probably longer than my lifetime to complete it, but I am glad to say the spirit of the country, particularly in the west, has gotten to the point where the people see the necessity of creating more water areas, and that is the big thing. We have got to have more water to provide our recreational facilities, and the only way to do it is to sell the idea to the people first and they will support it. When you consider that in a state like Kansas almost a quarter of a million dollars has been contributed in one year after but five years in the way of an educational campaign in this direction you will see that we have not such a big problem after all. It is largely a matter of going out and educating the people as to what we are trying to do for them.

MR. CHARLES O. HAYFORD (New Jersey): I am very much interested in Dr. Belding's statement, because I think it was in 1917 that Dr. Belding, Dr. Embody and myself spent four days studying out a program for this stream survey. I went ahead and completed ours so far as the streams go. We have in our state about four thousand miles of streams, only about a thousand of which are really adapted to trout. I feel that we have spent so much time in previous years discussing how to raise fish that it is well now to devote a little time to observing the results we get from those fish. Last year we asked the sportsmen when they took out a new license to make a report of the amount of fish they caught. Of course those figures are not accurate, but they do give some idea of what is taking place. In 1924, in a thousand miles of trout streams, they caught 168,242 trout, which is an average of 168 trout per mile. Each year since then it has been increasing, because we have put out more. Forty-four per cent of the licenses reported the results of their catch; thirty-three and a third per cent reported having caught no fish, and twenty-two and two-thirds per cent made no report whatever. It is evident, therefore, that the sportsmen are beginning to take more interest in the whole situation. In that period we have averaged planting about a million fish a year. Somewhere there is an eighty per cent loss from the time they leave the hatchery until they go into the

basket. Of course our state is small; we work on an entirely different system from that which prevails in most states, because there is no stream which we cannot reach with a truck in about six hours. We took all the knowledge the wardens in each county had, all the knowledge the biologists had, all the knowledge Dr. Embody had, and what little I had; we put it all together and started building up on it; whereupon we began to see a lot of interesting things in these different streams. The wardens are constantly checking; sometimes a warden will go up to a fisherman on the stream and count up his fish for that day. You can go out on a stream today and you will find one man will have three fish and another will have sixteen; you go along the stream three or four miles and you find they have not more than one or two in their basket. It seems to me that before we can arrive at anything very definite we have three important factors to consider: First, develop the hatchery to meet the conditions of your state. Second, you have to find out what results you get, and if you are not getting results you have to make a change somewhere, because if you do not there is going to be a lot of trouble. Now, where the trout ran 168,000, the bass report comes in at 121,320; in other words, they are practically catching a bass for every bass we put out. You take the pickerel—and we do not produce these in the hatcheries, but do stock them from the reservoirs. The pickerel catch was 190,829. Of course these are all given by counties; I am simply giving the totals. But it is very interesting each year to study the figures from the respective counties, having in mind the number of fish we are planting. I think that alone is going to help us a great deal in New Jersey. We hope as soon as we get a little further ahead to put a biologist to work on both the stream and the pond culture in the hatchery with a view to trying to eliminate a lot of the things that are going on now.

MR. DOZE: There is just one thing I want to suggest there: we find that screening off the small bass from the larger ones does not save the bass. Our loss in the bass is from the fingerlings eating each other, not from the adults eating the small ones.

PRESIDENT TITCOMB: Perhaps I could clear up one point on that Twin Lake proposition. All the bass of Connecticut are introduced species. They were introduced some sixty or seventy years ago, both the large-mouthed and the small-mouthed; and this lower Twin Lake had the large-mouthed bass introduced about fifteen years ago. Previous to that time the bullhead fishing was very fine. They have cleaned out all the bullheads. It seems to be an admirable place for them, too.

MR. BULLER: The black bass in the waters of Pennsylvania were also introduced there. While we have no lakes in our state except very small ones, we have noticed that in every lake into which the black bass has

been introduced, the black bass have destroyed the formerly splendid bullhead, yellow perch and pickerel fishing, and besides, it affords very little fishing of itself. That is true of every small lake we have in Pennsylvania. I am continually discouraging people from stocking small bodies of water with black bass, and trying to confine their distribution in the State of Pennsylvania, as far as I can to our rivers.

PRESIDENT TITCOMB: I am very glad you brought up that question. We are wandering from the subject but I want to agree with you in every word you have said; and it applies to all of New England and New York State. They have ruined some trout lakes so that they never can come back. We cannot get good bass fishing to supply the sportsmen as they want them, because the bass requires more cubic feet of water per fish than any other species I know of. Besides, we are depriving the multitude of people who like this pond and lake fishing of the opportunity to get quantities of food fish—simply to cater to a limited number of anglers who want the game fish. We have to guard against extending that damage any further than we have already done, particularly with the smaller bodies of water. Of course in the south the small ponds will support bass and produce quite considerable quantities of them, but here in the north they will not do it.

DR. BELDING: Will you state whether your remarks include both the small-mouthed and the large-mouthed?

PRESIDENT TITCOMB: I include both species.

# THE FOOD OF MINNESOTA FISHES WITH SPECIAL REFERENCE TO THE ALGAE

PATIENCE ELLIS KIDD

A survey of the food of certain Minnesota fishes was carried on at Big Sandy Lake, Aitkin County, northeastern Minnesota, during June, July, and August, 1925. Big Sandy Lake is formed by Sandy River which empties into the Mississippi River. Its contour is broken by long projecting peninsulas and several islands composed of glacial and modified drift. At its outlet is a government dam.

## METHOD OF WORK

Four collecting stations were located on beaches of fine sand and gradual slope; (A) south shore of Webster Bay, (B) north shore of Davis Bay, (C) northwest shore of Webster Bay, and (D) southwest shore of Webster Bay. In June the vegetation zone was fifty yards from the shore, but by the middle of August the water level had receded so far that the distance was only ten yards. The lowering of the water level undoubtedly affected the food supply.

Ten collections totaling 349 fish were made between June 13 and August 21, 1925. During June and July five collections were made at station A. During August two were made at station A and one each at the other three. Seven collections were taken between 9 and 10:00 P. M. and three between 4 and 5:00 P. M. The weather varied from cool to very warm and as a rule the water was calm. The greater part of the fish were taken with a medium-meshed seine, but a few were caught by hook and line. The fish were mostly small. Immediately after capture the fish were placed in 6 per cent formalin. Later the stomach and intestine were removed and preserved in formalin.

For study a single mount was made from the stomach or intestinal contents of each fish. The material in each mount was listed, each individual plant or animal being recorded. The algae were determined as to species, the animals only as to genus. Glycerine was added gradually to the mount and thus it was possible to keep the original mounts for future reference. A single mount for small or young fish would represent the entire contents of the digestive tract, with larger fish it might represent as low as one-fiftieth. For this reason the results are only qualitative.

## FISH

Three hundred forty-nine fish comprising nine species were examined. The species were:

1. Catastomus commersonii (Lapcepede). Common sucker. White sucker. Black sucker.
2. Notropis cornutus (Mitchill). Common shiner. Redfin. Silverside.
3. Percopsis guttatus (Agassiz). Trout perch.
4. Pomoxis annularis (Rafinesque). Common crappie White perch.
5. Ambloplites rupestris (Rafinesque). Rock bass. Red-eye. Goggle-eye.
6. Stizostedion vitreum (Mitchill). Wall-eyed pike. Pike. Pike perch. Yellow pike.
7. Perca flavescens (Mitchill). Perch. Yellow perch. Ringed perch. Raccoon perch.
8. Percina caprodes (Rafinesque). Log perch. Zebra perch. Hog Molly. Rock fish.
9. Boleo nigrum (Rafinesque). Johnny darter. Tessellated darter.

The digestive tracts of 54 were entirely empty; 55 contained recognizable plant food, mostly algae; and the chief food of the remaining 240 fish was Entomostraca and insects. The selection of food varied with the size of the fish and type of food available.

## FOOD

**Plant**—The "Water Bloom" varied in amount at different times in the lake. When there was a heavy coating of "Water Bloom" fish did not feed upon it and only when it was scattered throughout the lake was it present in the digestive tract of fish. The "Water Bloom" collected from the lake contained the following Blue-green algae:

Anabaena macrospora var. robusta Lemmermann.
Anabaena spiroides var. crassa Lemmermann.
Coelosphaerium Kuetzingianum Naegeli.
Gloeotrichia echinulata (J. E. Smith, P. Richter).
Microcystis flos-aquae (Wittrock) Kirchner.

Of the plants the algae alone play an important part in the food of fish. They form the basis of all fish food and the first element in their food chain. Some fish feed on algae directly, while others feed upon small fish and other herbiverous animals. The most abundant of the Blue-green

algae was Coelosphaerium Keutzingianum, of which 981 colonies were found in the digestive tract. It must be considered a selective food plant for the sucker, the shiner, the yellow perch, and the log perch. The green algae were infrequently taken, only eighteen pieces being recorded. From the standpoint of individuals, the 1592 diatoms constituted the most abundant group, but as regards total volume they were relatively unimportant, since one cell of Anabaena or one colony of Coelosphaerium contains a far greater amount of food material than a single diatom. In a few cases parts of a higher plant, a Potomageton, was found.

A list of the algae identified in the stomachs of the fish is as follows:

Blue-green algae (Myxophyceae, Cyanophyceae):
- Merismopedia elegans. A. Braun.
- Gomphosphaeria aponina. Keutzing.
- Coelosphaerium Keutzingianum Naegeli.
- Anabaena macrospora var. robusta Lemmermann.
- Anabaena spiroides var. crassa Lemmermann.
- Gloeotrichia echinulata (J. E. Smith, P. Richter).
- Microcystis flos-aquae (Wittrock) Kirchner—(infrequent).

Green algae (Chlorophyceae):
- Scenedesmus sp.
- Pediastrum sp.
- Closterium sp.

Diatoms (Bacillariaceae)
- Navicula
- Melosira
- Stephanodiscus
- Pinnularia
- Fragilaria

**Animal**—The animals found in the digestive tract of these fishes were rotifers, sponges, entomostraca, malacostraca, and various larval and adult insects. The absence of protozoan forms was probably due to rapid digestion. Rotifers were seen only in the sucker, but undoubtedly played a part in the food chain, since diatoms are their main source of food. Sponges were not in sufficient quantities to be an important factor.

Entomostraca constitute the most important food of the smaller fish. Two species of Cladocera, Daphnia and Chydorus, and the Copepods, Cyclops and Diaptomus, were identified. When the lake was covered with a heavy layer

of "Water Bloom", the fish contained practically nothing but Entomostraca, which evidently had been feeding on the "Water Bloom". A few Malacostraca of the genus Gammarus were found.

The insects were represented by the Pryganeidae, the Caddis flies, and the Corixidae, the Water-boatmen. Hungerford (1919) has shown that the Corixidae eat both unicellular and filamentous algae. The insect larvae were those of the midge, Chironomus, which according to Malloch (1915) feeds on diatoms, algae, and other vegetable matter.

## FISH

**Sucker**—The food of the sucker is equally divided between plant and animal forms. According to Hubbs and Creaser (1924), young suckers subsist on plankton and as they grow larger feed on the bottom ooze. The prevailing algae were Coelosphaerium, Gomphosphaeria, and Merismopedia. Among the diatoms, Melosira, Navicula, and Stephanodiscus predominated. The animal food consisited of entomostraca, rotifers, and sponges and in the larger specimens insect larvae.

**Shiners**—The observations of Forbes (1878) who found algae, insects, and dirt in the intestines were verified. The smaller shiners, below 2 inches, show a preference for Coelosphaerium, Melosira, and Entomostraca. Entromostraca and insects form the chief source of food of the larger shiners.

**Trout Perch**—The three specimens furnish scanty evidence regarding feeding habits, but they are sufficient to indicate that Entomostraca play an important part in the diet.

**Crappie**—Insects, especially the Corixidae, are an important element in the food of the crappie. Forbes (1880) notes that the Corixidae and Entomostraca are the main food of the young crappie and that other insects and fish are taken by the older fish.

**Rock Bass**—Forbes (1880) gives Corixidae and Entomostraca as the food of the young rock bass, and other insects and fish as that of the adult. We find that rock bass, 1-½ to 5 inches in length, consumes an equal proportion of animal and plant food. Even when there was no visible evidence of algae in the lake these plants were always found in the stomach of this species.

**Wall-eyed Pike**—Forbes (1880) reports that only very young pike feed on Entomostraca. Pearse (1918) states that their diet is mostly fish. In Big Sand Lake Entomostraca were the chief food of pike from 1-½ to 9 inches in length, together with a limited amount of Coelosphaerium, Anabaena, Stephanodiscus, and insects. Gammarus and small fish were found in pike over 2 inches in length.

**Yellow Perch**—Forbes (1880) found that perch feed on Entomostraca, Corixidae, and insect larvae. Pearse (1918) notes that the perch fed mostly on insect larvae and Entomostraca. Our results indicate that the chief diet is Entomostraca and insects, with a limited amount of plant food in the form of Coelosphaerium, Anabaena, Melosira, Stephanodiscus, and higher plants. The algae play a minor role as a direct source of food, although indirectly they furnish the food supply of the Entomostraca and Corixidae.

**Log Perch**—Pearse (1918), says that the log perch feeds by choice on the aquatic insects and their larvae. Turner (1921) finds that the young feed exclusively upon Entomostraca, turning to midge larvae and other small insects later. In a 2-½ and in a 3 inch fish, the stomach contents consisted entirely of algae. In other specimens algae were associated with Entomostraca.

**Johnny Darter**—According to Pearse (1918) the chief food of the Johnny darter is chironomid larvae. Our results indicate that algae augments this diet.

The writer desires to acknowledge the kind assistance and advice of Professor Josephine E. Tilden, Professor O. W. Oestland, Mr. R. T. King, Mr. Thaddeus Surber, and Mr. Eugene W. Surber.

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## PLANT AND ANIMAL FOOD OF FRESH WATER FISH

| FOOD | SPECIES OF FISH Sucker | Shiner | Trout Perch | Crappie | Rock Bass | Pike Perch | Yellow Perch | Log Perch | Johnny Darter |
|---|---|---|---|---|---|---|---|---|---|
| Merismopedia (Colonies) | (1) 5 | | | | | | | | |
| Gomphosphaeria (Colonies) | (1) 45 | | | | (2) 25 | | | (1) 42 | (1) 15 |
| Coelosphaerium (Colonies) | (11) 217 | (2) 102 | | | | (5) 34 | (4) 153 | (5) 260 | (1) 25 |
| Anabaena (Plants) | (3) 10 | | | | | (3) 5 | (7) 27 | (1) 2 | |
| Gloeotrichia (Colonies) | | | | | | | (3) 4 | | |
| Closterium | (4) 12 | | | | | | | (1) 1 | (1) 2 |
| Scenedesmus | | | | | | | | | (1) 1 |
| Pediastrum | | | | | | | (1) 1 | (1) 1 | |
| Diatoms: Melosira | (3) 110 | (2) 147 | | | (2) 157 | (1) 1 | (2) 26 | (5) 431 | (1) 155 |
| Stephanodiscus | (2) 56 | (1) 19 | (2) 6 | | (2) 17 | (2) 15 | (2) 21 | (5) 186 | (1) 48 |
| Pinnularia | (1) 1 | | | | (1) 7 | | | | |
| Navicula | (1) 113 | | | (1) 10 | | | | (1) 4 | |
| Fragilaria | (1) 2 | | | | (1) 5 | | | (4) 12 | (1) 8 |
| Rotifers | 20 | | | | | | | | |
| Sponge | 2 | | | | | | 2 | | |
| Entomostraca | 396 | 52 | 74 | 18 | 7 | 1117 | 6145 | 172 | 1 |
| Insects, imago | | 76 | | 27 | 6 | 24 | 64 | | |
| Insects, larva | 5 | 2 | | 1 | 2 | 11 | 22 | 47 | 44 |
| Gammarus | | | | | | 3 | | 1 | |
| Small Fish | | | | | | 28 | | | |

The number in parentheses represents the number of fish. The second number designates the individuals or colonies counted in one preparation.

*Discussion.*

Mr. Thaddeus Surber (Minnesota): Miss Kidd has presented this paper on the Food of Minnesota Fishes with the idea in view of calling your attention particularly to a certain phase connected with the correction of conditions in Minnesota that have been absolutely neglected in the past. Very few of us, I believe, realize the important part played by the presence of aquatic plants, especially algae, in the general scheme connected with a proper food supply for our native fishes. Miss Kidd has been working under the department of botany at the university for several years on this particular study, and during the past year has been employed by the Game and Fish Department of Minnesota to continue the studies begun in the university. At the present time the biological work that we are conducting in Minnesota with reference to lakes and streams is being carried on through the co-ordination of efforts made by the State Board of Health, the Department of Botany of the University, to a certain extent by the Department of Animal Biology, which is carrying on a more or less complete study of the parasites of fishes, and the Game and Fish Department. This, we believe, will have more effect on our plans for distribution in that state than any other one thing we could do. We have, as I said about two years ago before this society, as a result of surveys made in past years, been able intelligently to plant fish in many districts throughout the state. This is being enlarged so as to include as much as possible of the state, and will eventually include all the state. The legislature which adjourned along in April made ample provision for carrying on these studies. At the present time our own trucks are delivering to the streams through our regular hatchery employees the product of our hatcheries, the plants being based entirely on the investigations carried on by us in former years.

Mr. Johnson: I would like to add to what Mr. Surber has said that the University of Minnesota experiment station is carrying on a like survey. The work so far has been altogether a physiographic study, but the general aim of the project to be developed based on the physiographic study is a study of the productiveness of the lakes in fish food and an examination of the factors affecting it.

# NOTES ON THE USE OF THE BLACKHEAD MINNOW, PIMEPHALES PROMELAS, AS A FORAGE FISH

By Russell F. Lord, Jr.

*Aquatic Biologist, U. S. B. F.*

Last summer at the Fairport Biological Station, part of our pond program called for considerable work with forage fish. It was planned to experiment with various minnows in the hope of finding several species which might be good as forage fish in the bass ponds. Accordingly, numerous field trips were made to different ponds, sloughs, and backwaters of the local rivers to collect our stock. Only two suitable species however, could be obtained in sufficient numbers for practical experiments. These two were the Golden Shiner (*Notemogonus crysoleucus*) and the Blackhead Minnow (*Pimephales promelas.*) The following notes are on the latter species only.

Between the 1st and 15th of May 1926, 91 adult blackhead minnows were placed in B 13, a small pond only 3-100 of an acre in area. These fish, as far as the muddy water would allow, were kept under careful observation. When we cut down on the inflow however, most of the silt and mud settled out and observations were easier.

Six days after the last fish were placed in the pond, a piece of floating wood was found with many hundred, closely-arranged eggs adhering to the under-surface. The movements of well-developed embryos could be seen through the shells. A sample of these eggs was taken to the laboratory and placed in a battery jar for further observation. Hatching began in the afternoon of the same day and was still in progress the next morning. Almost all of the emerging fry however, were weak and dying, and before night all that had hatched, as well as the unhatched eggs, were dead in the jar in which they had been placed. Their mortality appeared to be due to rough handling or insufficient aeration.

After the discovery of the first eggs on the floating wood, several boards about 3 x 10 inches in size were placed along the banks of the pond about 8 inches under the surface of the water. It was thus easy to take each board up for examination every day and then replace it in the soft pond bank. These nest boards were given numbers, and, as I just mentioned, were examined daily. During the season twenty such nests were under direct observation, and the presence of several other nests out of reach on the under-surface of the vari-

ous pipes and platform supports were indicated by the actions of guarding fish. The last eggs were observed on August 6.

Data secured on the twenty accessible nests are as follows:

The time from the first appearance of eggs to eyeing averaged 4 days.

The time from the first appearance to the beginning of hatching averaged 6 days.

The average time from appearance of eggs to entire hatching averaged 9 days.

The water temperature during the spawning months was: May 68.23, June 74.28, July 79.04, August 79.73. At these temperatures (av.) the eggs of Pimephales promelas thus required a period of 6 days from laying to hatching. Hatching continued for 2 or 3 days. This was not surprising as I soon noticed that all the eggs were not placed upon a nest board at once, but some times in as many as four successive lots, and they eyed up and hatched in the exact order of their appearance upon the nest board.

No special attempt was made to see if all the eggs of a certain nest were from the same female. Two fish, however, a male and female, were all that were ever seen near a nest at the same time. They usually kept immediately under the eggs and were very active, moving fins, tail and body constantly. Of the two, the male fish was always the more aggressive, and when attempts were made to catch various males with a dip net, they would swim under, over and around it, but refused to be frightened away from the nest permanently. When both fish were present, the female kept quietly under the nest board at the shore end and after being disturbed always returned to the same position.

The protective instinct seems to be highly developed in these minnows. To illustrate, on May 28, two males were found fighting vigorously. The scene of action was close to the nest of the larger fish, which had been observed often enough to be easily recognized, and hostilities had evidently begun when the smaller male had discovered the loss of his entire nest and had gone in search of it. (I had removed this nest to another pond to see if the eggs would hatch without parental protection). The large male on guard at his nest however, had resented the inquiring stranger and had been quick to defend his own eggs. The two fighting fish had a firm grip on each other's jaws and were shaking one another viciously. As they approached the surface of the water, I caught both of them

with one dip of the net. Both were male fish in full breeding dress. The color was deep black, especially about the head, with two large bands of gold from the belly part way up the sides, and a third smaller patch of gold near the belly side of the peduncle. Tubercles were prominent on the snout. These two fish were returned to the pond uninjured, and next day found the larger one on duty at his nest.

On other occasions the guarding males would nibble at investigating fingers whenever a nest board was touched. They appeared to become more fearless as the hatching time approached. Such a display of aggressiveness seemed to be essential as many times large water beetles and water bugs, both adults and larvae, were taken in the act of destroying the eggs on some nest board. In fact, when the nests were transferred to other ponds in which these beetles were abundant it was necessary to protect them with fine wire screen.

The first large sample of blackhead fingerlings was measured on August 17. As spawning had been more or less continuous from May 21 or earlier, to August 6, it was not surprising to find fish varying in size from 8 to 40 mms. There was a fairly even distribution from the very smallest to those in the 40 mms. class.

Although over a thousand fingerlings had been seined out as forage for our young bass during the summer, the minnow pond was found to be swarming with young fish when it was drained on October 14. The minnows were first culled by allowing the smaller ones to pass through the meshes of a net that retained the larger ones. Four hundred and fifty-eight larger fingerlings were thus separated and counted by hand. On examining these fish, I was surprised to find only one individual which was clearly an adult. The rest of the large minnows were very uniform in size and were no bigger than some other blackhead fingerlings that had hatched in early June. This comparison was possible because accurate check was kept on fish hatched from a nest that was transferred to a pond where no other fish were present. This fact, coupled with that of my finding numerous dead adults at the height of the spawning, indicates a considerable mortality of brood fish at this time. It is however, too early for definite conclusions in this respect.

The smaller minnows were weighed at a rate of 500 fish to 3 ounces, and a conservative computation showed a production for the pond of 6,500 new individuals of this size, and a total for the pond of 6,867. The production of blackhead minnows

per acre on this basis stands at 201,971 at approximately 119 pounds.

So much for the last season's observations. At that time we wondered if the largest fingerlings would spawn this year. Accordingly 20 females and 15 males of last year's hatch were placed in a concrete pond on May 7th. Eggs were found the next day on pieces of tile placed for the purpose. These eggs were destroyed by some enemy, and no more were found until May 17. From that date on to the last observation I have, July 16, eggs were always present in the pond. About 4,000 fingerlings have already been seined from the pond, and it is still full of blackheads of all sizes.

What then, are the possibilities of the minnows as a forage fish for bass or other carniverous pond fishes? Of course, a single summer's observations, or even the data of two summers, are not sufficient for too exacting conclusions, but our present information points to its being a good fish to get acquainted with. Summarizing we note that:

1. After a size of 25 to 30 mms. was reached the fish were observed feeding on algae to a great extent. It is thus non-competitive with game fish.
2. The species was very prolific, having increased in numbers about 75 times by the end of a summer.
3. It spawned on boards or tile placed for the purpose. Thus its distribution to other ponds is made easy.
4. The spawning season was of long duration. This would provide both small and large bass with a supply of fish food throughout most of the growing season.
5. The earliest hatching fingerlings of one season are ready to spawn the next. This assures a supply of brood fish.

Furthermore, this minnow appears to be a natural food for the game fish.

A few trials made during the past summer showed that bass readily took to these minnows—in fact took to them too well. For example a nest placed in a bass rearing pond had no survivals, and from over 1,000 fingerlings placed in another bass pond none were recovered when draining in the fall. Another large nest of eggs in hatching condition was placed in a crappie pond on June 24. When this pond was drained on

September 21 there was a survival of only 4 minnows out of hundreds that must have hatched. The crappie from this pond were reported to be in better condition than in other years and we might conclude that the minnows were somewhat responsible for this.

Reports this year show that bass fingerlings in ponds stocked with spawning blackhead minnows are growing faster than bass in ponds of the same size where there are no blackheads. Of course, some objectionable things might be discovered about this fish. For example it has been accused of eating bass eggs. Personally, I do not see how it can do this with a vicious, alert male bass guarding the nest. Perhaps it would pick up eggs from a deserted nest. However, as both bass and the blackhead spawn at the same time, and the blackhead continues for a longer period, it would seem that the domestic duties of the minnow would keep them from doing much raiding. In my opinion the danger would be mostly for the minnows.

I believe therefore, that the species might be of real value in pond culture. Its exact superiority or inferiority to other forage minnows must, however, be determined by more detailed experiments in the future.

### *Discussion.*

MR. ADAMS: I would like to ask if the adult blackhead minnows might be a menace to black bass fry.

MR. LORD: I would say not, but you could not prove it until you put them in with the fry and determined whether any could be found inside the minnow.

MR. ADAMS: You have not made any experiments on that line?

MR. LORD: No, we have not made any special experiments to prove that. The blackhead minnow, after it reaches a certain size, say forty millimeters, can be seen browsing along on the stems of aquatic plants, scraping off the diatom slime and small algae. It is not a carniverous fish so far as can be seen. It is not like the horned dace, which is very carnivorous.

MR. GREELEY: With regard to minnows eating the eggs and fry of other fishes, I do not know that there has been any observation made on the blackhead. But one time last summer I saw a rock bass on its nest. There were sac fry in the nest, and some blunt-nosed minnows came along—Hyborhynchus notatus. I watched them carefully, and if they did not seem to be hunting after those fry, I do not know just what they were doing. This rock bass was very tame and I tried to see how close I could get, and in so doing I chased it off the nest. It came back

soon and chased all the minnows off again. I chased it off the nest again and the minnows came back. I made another observation on the Conoga marsh on Cayuga Lake of the large-mouthed bass, this time with two different minnows, the golden shiner (Notemagonus crysoleucus) and the Cayuga minnow (Notropis bifrenatus). In this case I watched the bass nest very carefully. When the bass was on the nest there were no minnows on the nest, but as soon as the bass left the nest—on account of my presence, of course—I saw minnows of both species go on the nest and apparently hunt out the eggs. From another nest, but under the same circumstances I caught some minnows, and in the two stomachs I examined—unfortunately I had not time to examine them all —I found no traces of eggs. I do not know whether not being able to find the eggs proves it or not.

PRESIDENT TITCOMB: This is a very interesting paper. Dr. Moore last year brought forth some information about this same minnow; I wonder if she can give us anything now?

DR. EMMELINE MOORE: No, I cannot. Perhaps Dr. Embody can.

DR. EMBODY: No; Mr. Greeley here was the one who made the observations last year. He can tell you what he found out last year about the spawning.

MR. GREELEY: We found nothing that Mr. Lord has not covered very much better than I could. One thing that was quite remarkable was the pugnacity of the fish. If you put a stick down there, these little male fish, three or four inches long, would hit at that stick very viciously. It shows that they defend their eggs very well against enemies, and I believe it is entirely necessary to defend eggs held in a situation like that, so exposed, because if they were not defended there certainly would not be any.

DR. HUBBS: I made some observations on the spawning of the Pimephales promelas this summer in northern Michigan. I also made some observations on the bass nests, and certainly as soon as the bass leaves the nest for any reason, even if he is chasing another fish off the nest, the minnows will dive in, sometimes by the scores; so I think there is no question they do get some of the eggs. The question of the use of Pimephales promelas as a particular minnow for forage fish would be a difficult matter over a good deal of the eastern part of the country, because he is generally pretty rare. They happen to be commoner further west of the Mississippi than they are east. In general they are not common, but where they are found they are apt to be very abundant. You will find the blackhead minnow abounding in a lake where there are very few competitors. Apparently they can live in almost any kind of water, because in dried up areas in North Dakota where almost nothing but a stickleback can exist, these minnows can be found. They can stand competition, and I think that is the secret of their distribution.

A minnow which is closely related to it and looks a good deal like it usually occurs in abundance in situations where the other is not found, and I imagine very much the same results could be obtained from the other one. They have the same breeding habits, and are practically identical as far as I know.

MR. ADAMS: I hope this investigation will be continued with a view to our getting eventually an adult minnow of some species which, for example, we could put into our bass ponds and which would breed and produce the small fry for growing small bass. If when the adult bass are taken out of the pond and the eggs have hatched we could put in there any kind of minute minnow life that these bass after they got to be a certain age could feed on, obviously it would be a splendid thing. It is a great satisfaction to me to see some of these younger folks here take hold of this work and come here and make these reports.

MR. HAYFORD: In a pond this year a little over an acre in extent we put a thousand golden shiners. We did not try to force them along, and they are now about an inch long. We have another pond of these shiners, of the same age which we gave all the food they could eat, and they are now two and a half inches long. If you net these shiners out and put them in the ponds where the bass are, you should not put in more than they will eat that day, because they are very suspectible to fungus in warm weather, and you will get ichthyophthirius. We grow small-mouthed bass in two months from two and a half inches to four inches. They grow at a tremendous pace; all they do is eat. We took a young bass about two inches long that we had stuffed with mosquito larvae, and upon examining it we found 118 of them in his stomach, so there is no doubt that the beggars are hungry.

I am very much interested in this minnow question, because I believe we are only at the beginning of pond culture. While the figures I gave a few minutes ago may not seem much at this time, when we get them year after year it is going to give us something to work on. I understood Dr. Davis to say that the golden shiner was largely vegetarian and that there was no danger of his harming the bass to any extent. For that reason when he was there last spring we acted on his advice. These golden shiners when they are an inch and a quarter long will eat sheeps' liver or plucks just like young trout. You can do almost anything you like with them.

MR. ADAMS: You have an available food supply, then, for your bass, particularly the adult bass that you may keep for brood stock?

MR. HAYFORD: Yes. We will take a pond and hatch all the bass we can in that pond; then we will take another pond and hatch all the golden shiners we can. We will get much better results for having taken one pond for shiners and one for bass than for having taken two ponds for bass.

MR. DEROCHER: A gentleman told me he had planted some golden shiners in a pond and that now the pond was being overrun with them; that the trout did not seem to bother them. I told him that was something new to me, because to my knowledge the trout would take the golden shiner very readily.

MR. HAYFORD: Of course there might be enough other food, you know, in the ponds.

DR. DAVIS: I think there is one great advantage that the blackhead minnow and the golden shiner have over some others that have been advocated for this purpose, and that is a long spawning season. In the case of the blackhead minnow and the golden shiner they spawn at Fairport until well into August, so that we have young fish continually coming on, just the right size for the fingerling bass to pick up.

PRESIDENT TITCOMB: I quite agree with you.

MR. HAYFORD: We have spring water in Hackettstown and we can hold these golden shiners in the spring water in the spring of the year and make them spawn almost any time we like, either after the bass do or before.

# TOXICITY EXPERIMENTS WITH FISH IN REFERENCE TO TRADE WASTE POLLUTION

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## I. THE PROBLEM OF WATER POLLUTION

Of the various problems confronting our fisheries, the one which demands the most immediate attention is the water pollution. If allowed to increase, it means the serious depletion and even ruin of a great part of our inland and coastal fisheries, and the longer it remains unregulated, the more difficult will become its ultimate control. Already it has made such inroads that the restoration of many heavily polluted streams is practically impossible. The water pollution evil is not a mere local issue; its scope is national, and its elimination requires concerted action. The battle for unpolluted streams must be fought simultaneously throughout the country by a well organized campaign.

Obstacles.—The elimination of water pollution means overcoming many obstacles, especially in organizing a co-operative campaign among states where local conditions, different laws, and divergent forms of pollution present numerous complications. The antagonism of the manufacturing interests must be overcome and indifferent public opinion aroused by a campaign of education. Laws must be carefully drawn and must be sufficiently broad in their application, as well as rigid in their enforcement to facilitate the handling not only of transitory pollution, but also of cases where polluting material is surreptitiously emptied into a stream under the pretense of a nominally operating disposal system. The present lack of definite knowledge as to the quantity and kind of pollution which will injure fish life is a serious handicap. Since the cost of freeing badly polluted streams in heavy manufacturing centers is prohibitive, it may be advisable to allow them to continue to serve as sewers for waste disposal, but in border line cases which demand a careful consideration of all conditions, proper standards for determining whether or not a stream should be cleared of pollution are badly needed.

Effect on Fish Life.—Two kinds of water pollution affect fish life, sewage and trade wastes. Sewage enters the stream from private toilets and cesspools, and in the form of effluents from municipal systems. Owing to its prominence as a public health factor, methods of disposal have been devised by which

it will eventually be controlled. If unregulated, it damages water supplies and manufacturing interests, endangers public health through contamination of edible shellfish, and is injurious to fish environment. Trade wastes include all forms of waste material from industrial sources. Fish preservation is concerned chiefly with this important type of pollution, which directly and indirectly destroys fish life.

Acting directly, pollution reduces the oxygen supply, renders fish unfit for food, drives them from their habitat, and causes death or predisposition to disease. Indirectly, it may cause destruction of eggs and young, reduction of the spawning grounds, changes in bottom and vegetation, and limitation of food supply. The effect of severe recent or transitory pollution in flagrant cases is conspicuously indicated by the presence of dead or dying fish, but unappreciable continuous pollution may be fully as harmful due to a cumulative effect over a long period.

REMEDIAL MEASURES.—Constructive work, in order to avoid strong opposition, must be undertaken gradually. In the first place, new pollution must be prevented; secondly, small streams with few sources of pollution must be cleared; and finally, through the cooperation of manufacturers, the pollution in the larger streams must be eliminated or diminished. The manufacturers can be influenced by the diplomatic but forceful handling of each case. As a last resort in refractory cases where moral suasion is of no avail, rigid enforcement of laws must be invoked. To insure such action simple, direct, readily enforceable laws are necessary. Favorable public opinion is absolutely necessary for the successful enforcement of laws. It may be obtained by making an appeal through the medium of pamphlets, posters, magazine and newspaper articles, and lectures on the basis of fair play, loss of outdoor enjoyment, and danger to public health.

INVESTIGATIONS.—The ultimate solution of the problem of water pollution involves certain biological investigations: (1) Suitable means must be found for eliminating various types of trade wastes. (2) Standards for judging as to when a stream is polluted must be determined. These standards must be applicable to different types of streams and to various kinds and concentrations of water pollution, in order to ascertain the maximum amount each stream may handle with safety. (3) The direct and indirect effect of the various constituents of water pollution upon fish life must be observed.

Since the factors involved in these biological problems are so complicated, the immediate and ultimate effect of various types of trade waste pollution must be carefully studied before we shall be in a position to determine the exact amount of pollution fish can survive or to formulate standards for judging the amount of pollution any given stream can handle.

## II. FACTORS INFLUENCING EXPERIMENTAL STUDIES UPON THE EFFECT OF WATER POLLUTION ON FISH

The chief obstacle in obtaining accurate data relative to the effect of various inorganic and organic wastes upon fish life is the difficulty of controlling the various complicating factors which enter into an experiment. Unless their influence is recognized, errors of interpretation are inevitable. As a rule the conditions, under which these experiments are made, are far from ideal. Field tests must be performed in an environment in which exact laboratory technique is impossible. Necessarily, all experimental work of this nature should be most throughly scrutinized before acceptance.

### 1. FISH

The selection of the fish for experimental work is of primary importance. All possible safeguards should be taken to secure healthy, normal individuals, since disease and weakness render them susceptible to changes in environment.

INDIVIDUAL VARIATION.—Individual fish, particularily if diseased or weak, vary considerably as to the lethal dose, and unless an ample number of suitable controls are used results may prove untrustworthy. Even healthy fish of the same size, weight, and appearance may show several hours differance in the onset of symptoms and time of death.

FAMILY.—Certain families are more resistant than others, e. g., Cyprinidae vs. Salmonidae. Hardy fish exist where the more delicate cannot survive. With unfavorable changes in environment, the more susceptible fish are the first to perish, although if destruction through natural agencies is limited to a habitat frequented by certain species, it may appear otherwise. Certain families may be resistant to one form of trade waste pollution and susceptible to another, e.g., perch and bass. Obviously, it is impossible to make adequate comparisons as

to the toxic effect of various chemicals unless tests are made with the fish from the same family. Even then the lethal dose for one species may not correspond to that for another.

SPECIES.—A difference in susceptibility between members of the same family is shown by the action of copper sulphate upon Chinook salmon, brook trout, and rainbow trout, which were held in the same pool. The solution which was sufficient to cause the death of all the salmon and seriously effect the brook trout, producing marked symptoms and causing a few deaths, had no apparent effect upon the rainbow trout. The well known resistant qualities of the rainbow trout and the susceptibility of the salmon hold true in protection against chemical poisons.

AGE.—Observations upon fingerlings and adult brook trout indicate that there is a difference between young and old in their resistance to disease and to toxic substances. Brook trout fry are relatively immune to infection with B. salmonicida, whereas adult fish are extremely susceptible. Fry in the yolk sac stage withstand certain trade wastes better than older fry or adult fish. Young fish are more resistant than older fish to some chemicals and less resistant to others, e. g., fingerling trout appear more resistant to carbolic acid, a corrosive poison, and more susceptible to hydrochloric acid than adult trout.

SIZE AND WEIGHT.—The difference in the resistance of old and young fish may be due in part to age and in part to size, weight, and greater surface area which produce greater demands upon the body metabolism. A comparison of the oxygen requirements of forty-one 19 cm. and eighteen 26 cm. trout with the same combined weight illustrates the latter point. The larger trout showed earlier symptoms of distress and consumed during the first two hours nearly twice the quantity of dissolved oxygen used by the smaller fish.

VITALITY.—Experimental results depend upon the general condition of the fish. Vitality varies at different seasons. It is lowest immediately after spawning, during extremely warm weather, and during periods of food scarcity. Although fish reared under artificial conditions have not the vitality of the wild stock, they undergo confinement better and are preferable for experimental work of this character. The active, darting, nervous species tend to perish when closely confined.

## II. ENVIRONMENT

WATER.—The constituents of the water may alter the effect of certain chemicals, e. g., the lethal dose of copper sulphate has been observed by Marsh to vary in different waters from 1:400,000 to 1:6,500,000. In certain waters the presence of carbonic acid may change ammonia to the less toxic ammonium carbonate, sulfids may be more quickly oxidized to sulphates, and buffer action may influence the hydrogen-ion concentration. The waters favorable to fish life will produce a more sturdy species than an unfavorable environment.

Toxicity experiments in a new environment are apt to record an abnormal susceptibility on the part of the test fish, e. g., the transfer of alewives or even the hardy bullhead to cold spring water rapidly lowers their resistance.

CONTAINERS.—The ratio of the size and number of the fish to the container is important. Goldfish, which are accustomed to aquarium life, may be successfully tested in small containers for long periods, whereas large fish die rapidly because of oxygen depletion, increased carbonic acid, and injury in the cramped quarters.

FLOW OF WATER.—Tests with chemicals are most satisfactory when made without change of water. The solution should be of uniform strength before the fish are added. If tests are made with flowing water some method of producing a constant uniform concentration must be devised. Mechanical injury, such as forcing weakened fish against the screen at the lower end of the pool must be avoided.

OXYGEN.—The amount of dissolved oxygen in the water has a direct bearing on toxicity tests. Each species of fish requires a minimum oxygen level for existence and a higher one for normal existence. Unless the surface area of the container is sufficient to supply the necessary oxygen during the course of the experiment, the influence of diminished oxygen must be counteracted by some form of aeration. With trade wastes which have an oxygen demand sufficient to reduce the dissolved oxygen below the point of tolerance, it is difficult to separate the effect of oxygen depletion from chemical poisoning, e. g., with hydrogen sulfid, the dissolved oxygen is decreased with the concentration of the gas and a double effect is produced, hydrogen sulfid poisoning and diminished oxygen.

TEMPERATURE.—Cold water fish can stand a comparatively high temperature when the change is gradual, but sudden

changes may prove destructive. Brook trout are killed by a rapid transfer from 55 to 80 degrees Fahrenheit. Extreme fluctuation in night and day temperature has been observed to cause a high death rate in brook trout fingerlings. Increased temperature, by lowering the vitality of the fish and favoring the growth of the infecting organism, plays an important role in fish epidemics. Similarly it produces more rapid destruction of fish by chemical pollution; e. g., the lethal dose of hydrogen sulfid for carp at 40 degrees Fahrenheit was 34 p.p.m. and at 65 degrees 6 p.p.m.

## III. TOXICITY STATISTICS

These variable factors indicate the difficulty of obtaining accurate results in field and laboratory studies of the effect of chemical wastes upon fish and explain the discrepancies in the results of different investigators. They emphasize the importance of carefully controlled tests and the necessity of determining the minimum lethal dose of each chemical for various species of fish in order to establish standards.

Our laboratory and field experiments deal with a single phase of the pollution problem, the immediate effect of certain chemical constituents of trade waste pollution upon young and adult fish. Observations are limited to the symptoms and mortality occurring within twenty-four hours. Although these crude tests determine the concentration which fish may withstand for twenty-four hours, they give no information as to the effect of weaker solutions acting over a longer period of time. For the sake of completeness we have compared our results with the statistics of previous investigators.

METHODS OF WORK.—The chemicals used in these tests comprised acids, bases, salts, and gases, either constituents of trade wastes or remedies used empirically by fish culturists in the treatment of fish diseases. Unless otherwise specified, the chemicals were of high grade purity. Brook trout, rainbow trout, chinook salmon, carp, goldfish, and suckers were used. Owing to their sensitivity to changes in environment brook trout proved the most satisfactory indicators, although carp and goldfish were more convenient to handle. For most tests two to three year old trout averaging about 26 cm. in length and 215 grams in weight were used. Carp, suckers, and goldfish were employed for tests with hydrogen sulfid and paper mill wastes.

The trout were held without change of water in four wooden tanks containing 780, 646, 147, and 147 liters respectively. Five adults were placed in the larger tanks and two in the smaller. Control tests showed that this number survived without discomfort in these tanks for longer than twenty-four hours. The temperature of the water ranged from 53 to 60 degrees Fahrenheit, averaging 56. In a few instances tanks which received a slow seepage of spring water were used. Gasoline, petrol, leather board, paper mill, and wool scouring waste tests were conducted in tanks and in Chase hatching jars. For laboratory experiments with sodium and hydrogen sulfid, 50 liter glass aquaria supplied with air forced through a Berkefield filter were used. In field work with paper mill waste and hydrogen sulfid, large wooden wash tubs proved convenient.

SYMPTOMS.—Chemical poisons produce certain general symptoms, but the various substances differ qualitatively as to selectivity of symptoms and quantitatively in the rapidity of onset and course of development. The general type and specific characteristics of the chemical determine the symptomatology. At times the selective action of the poison is sufficiently defined as to be of diagnostic value. The early symptoms are more important from the standpoint of differential diagnosis, since the late symptoms are usually confused with those present in all dying fish.

In order to be available for ready reference, the characteristic symptoms produced by twice the minimum lethal dose have been tabulated for the various chemicals (Table 1). A description of the general symptoms in chronological order is given first, and under the individual chemicals, attention is called to those of diagnostic importance.

1. IRRITATION.—The first noticeable sign after the fish is immersed in the chemical bath is increased activity in the form of swimming, wavy movements and rubbing the body against sides of the tank. The degree of activity and rapidity of onset varies with the chemical. With the more irritating chemicals the fish becomes covered with a grayish mucus, evidently a protective reaction. Its absence in the salmon may explain the relative susceptibility of that species.

2. INACTIVITY.—The period of activity is followed ordinarily by a period of sluggishness, in which the fish lies inactive at the bottom of the tank. Response to stimulus during

this stage is particularly poor and even during the active stage is below normal.

3. SWIMMING.—The fish first shows restlessness by incessant movement through the water. At times it apparently tries to get out of the noxious environment. Then its movements become more irregular and it aimlessly wanders around the tank, frequently striking the sides. It may glide quickly to the surface and occasionally leap from the water. Intervals of resting at the bottom and surface swimming follow, the movements becoming more and more incoordinate.

4. OXYGEN HUNGER.—Oxygen hunger is manifested by surface swimming and gulping air. It is due either to lack of dissolved oxygen or to interference with gill function.

5. EQUILIBRIUM.—With the approach of death the fish loses its powers of equilibrium. Suddenly it turns on its side and swims with a convulsive flutter. Sometimes it is able to right itself, but more often there is increasingly feeble and spasmodic swimming on the back with slow irregular respirations.

6. RESPIRATIONS.—The respiratory movements of normal trout range from 90 to 100, averaging about 95. Owing to individual variation, it is difficult to determine accurately changes in respiration. With some chemicals there is a temporary increase in the respiratory rate, with others no change or a slight decrease; but with the onset of marked symptoms of discomfort and with the approach of death practically all fish manifest some form of slow convulsive respiratory movement.

LETHAL DOSE.—The minimum lethal dose for the various chemicals is given in Table 2. It represents the lowest dilution capable of producing death within twenty-four hours. For comparison the statistics of other investigators have been included.

1. HYDROCHLORIC ACID.—With minor differences hydrochloric, nitric, and sulphuric acids produce the same general type of symptoms in trout and differ chiefly in respect to the lethal dose. The effect of an acid upon fish depends both upon ionization and upon inherent toxic properties. The toxic dilution of these acids ranges between a pH of 4 and 5, yet fish have been found in waters as acid as pH 4.6.

Hydrochloric acid is used in plating and in the manufacture of chemicals and dyes. The characteristic symptoms are gradual onset, early surface swimming, lack of response to stimuli, and a mucous coating. There is terminal loss of equilibrium, irregular slow respiration, and frenzied rushing. The minimum lethal dose is 1:100,000, which is stronger than that obtained by other investigators.

2. NITRIC ACID.—Nitric acid is used in the manufacture of fertilizer, chemicals, munitions, etc. It acts more rapidly than hydrochloric and suggests the action of toxic factors other than ionization. The chief characteristics are marked irritation and activity, rapid formation of mucus, decreased forceful convulsive respiration, early loss of equilibrium, and frenzied rushings, particularly in the terminal stages.

3. SULPHURIC ACID.—Sulphuric acid is used in wool scouring, nail and iron works, and in the manufacture of munitions, chemicals, and starch. The onset of symptoms is slower, activity is less noticeable, and sluggishness is more marked than with hydrochloric and nitric acid. There is no frenzied rushing or convulsive actions. The fish, covered with mucus, swim slowly and blindly around the pool aimlessly bumping the sides.

4. ACETIC ACID.—The organic acids present greater diversity of action than the inorganic acids. Acetic acid is used by fish culturists in the treatment of diseased fish. Trout can survive for a short time immersion in a dilution of 1:200. The symptomatology presents no characteristic features; slow onset, moderately increased activity followed by sluggishness, and the formation of a protective covering of mucus.

5. CARBOLIC ACID.—Carbolic acid is characterized by its corrosive action. The most striking feature is its rapid and severe irritating effect even in high dilutions. The fish immediately endeavor to rub off the irritating substance by rolling over on the bottom and by rubbing against the sides of the pool. They show no evidence of oxygen hunger and seek the corners of the pool. In dilute solutions the fish soon lose their equilibrium and lie on their back or side for several hours before death with spasmodic twitching of head and tail. The respiratory movements are slightly increased, become irregular, forceful, and jerky. Dying trout show a general congestion of gills, liver, and viscera.

6. TANNIC ACID.—Tannic acid, an astringent derived from galls and closely related to gallic acid, is used in the manufacture of ink and leather. Trout gradually become uneasy, swimming restlessly to the surface with oxygen hunger and then lie quietly on the bottom with respiration noticeably quickened. Increasing signs of discomfort terminate in erratic swimming, surface jumping, loss of equilibrium, and death. The rapid respiratory rate and oxygen hunger indicate injury to the gills.

7. AMMONIUM HYDROXIDE.—The action of the three alkalis, ammonium, potassium and sodium hydroxide, differs only in degree of toxicity. Ammonium hydroxide is a product of gas and ammoniacal works, the effluents of which have been found to kill fish. The symptoms are rapid and fulminating. The fish dash wildly about, jumping and thrashing at the surface. With the minimum toxic dose signs of irritation appear in two and one-half hours and in three hours the fish turn on their backs with altered respiration and spasmodic struggling. Respirations are markedly decreased and death occurs after five hours. On removal to fresh water dying fish recover in six hours. The symptoms increase with the strength of the solution. In ten times the toxic dose there is immediately frenzied rushing, jumping out of the tank, and swimming on back in 15 minutes. The hydroxide is changed to the less injurious carbonate by free carbonic acid, and therefore the action of this chemical varies in different waters.

8. SODIUM HYDROXIDE.—Trade wastes containing sodium hydroxide are derived from a number of industrial processes. It produces an irritating effect upon the fish which rapidly become covered with mucus. In strong solutions the movements of the fish become sluggish. It comes to the surface gasping and blindly bumps the sides of the tank. In the minimum lethal solution it remains at first quietly at the bottom and then comes to the surface gasping. Later it lies on its back with periods of rapid dashing and leaping. The strong dilutions rapidly inhibit the respiration, but with the minimum lethal dilution no change is noticed for the first two hours, then the respiratory movements become slow and feeble and after the loss of equilibrium show marked irregularity.

9. POTASSIUM HYDROXIDE.—Potassium hydroxide produces the same train of symptoms as sodium hydroxide, namely, sluggishness, irritation and distress, oxygen hunger, decreased respiration and loss of equilibrium. With solutions of similar

strength the action is less marked than that of sodium hydroxide.

10. ARSENATE OF LEAD.—The particular preparation used contained 12.5 per cent of $As_2O_5$, 31.5 per cent of Pb $O_2$, 0.75 per cent of water soluble arsenic and moisture not over 50 per cent. It is used for spraying trees. Its slow action produces no characteristic symptoms in fish.

11. CALCIUM HYPOCHLORITE.—The toxic action of calcium hypochlorite depends upon the free chlorine and therefore is transitory. With strong solutions the fish pass at once into a stage of irritation, followed by sluggishness and lack of response to stimuli. With dilute solution the onset is insidious and the two stages occur together. The respiratory movements are increased. The fish rubs its body against the sides of the pool and swims to the surface with increasing frequency, which finally culminates in rushing and leaping at the surface and spasmodic gasping. With loss of equilibrium the fish rests head down in the water, turning with a top-like motion. Then it settles to the bottom where it repeats from time to time the rushing tactics which each time become more feeble. The smaller trout were less affected than the larger. The extreme oxygen hunger, surface rushing, and peculiar head balancing are of diagnostic importance.

12. COPPER SULPHATE.—Copper sulphate is used as an algacide for water supplies. Owing to the extreme range of toxicity for different species of fish and for various waters, it is difficult to determine the quantity which may be used for algacidal purposes without injury to fish life. The fish first shows increased activity and then lies sluggishly on the bottom with increased spasmodic respiration. Occasionally it darts through the water rapidly, usually inclined slightly to the side. Loss of equilibrium follows, the fish remains quiet and unresponsive to stimuli, and occasionally struggles to the surface. The effect of the poison persists even after transfer to fresh water which does not save the life of the fish.

13. FERROUS SULPHATE.—Ferrous sulphate occurs in wastes from iron and nail works. With the exception of Clark and Adams, observers find that iron salts have a relatively low toxicity. There is nothing characteristic about the symptoms, which develop slowly.

14. MERCURIC CHLORID.—This chemical is used as an antiseptic. It acts as a tissue coagulant. At death the aur-

icles are filled with blood and the gills pale. The fish, apparently unaffected at first, die suddenly without noticeable symptoms.

15. POTASSIUM PERMANGANATE.—Fish culturists use this antiseptic for the treatment of diseased fish. Fish immersed in strong solutions recover promptly when placed in fresh water. The skin acquires a yellow tinge from the chemical and the gills are deeply injected. The chief symptoms are surface swimming and leaping.

16. HYDROGEN SULFID.—This gas produces in man acute and fatal poisoning in chemical works and sewers through its action on the respiratory tract. It is one of the most toxic of the coal tar wastes. It is associated with decomposition of wood pulp and is formed in small amounts in nature. Since potassium and sodium sulfid hydrolize into hydrogen sulfid in the blood their action is similar. Small amounts are without perceptible effect but larger quantities paralyze respiration. Since it is oxidized rapidly in the body it has no cumulative action. The limit of tolerance of different species of fish has a wide range. Its action depends upon the concentration of the gas and the temperature of the water.

The chief symptoms are irritation, frenzied rushing, respiratory paralysis, partial recovery of respiration, stupor, loss of equilibrium, oxygen hunger, and recovery on removal. The respiratory changes are diagnostic. There is an initial lowering or suspension of respiratory movements followed by a partial recovery and subsequently a decline in rate with increasing irregularity.

TRADE WASTES.—The lethal dose of the trade wastes varies with their composition and dilution. In addition to their chemical constituents certain wastes tend to reduce the supply of dissolved oxygen in the water.

The sulphite liquor from paper pulp manufacture has a slow action. It produces no special symptoms beyond those usually observed in dying fish. Leather board waste acts in a similar manner. With wool scouring waste, which usually contains sulphuric acid and organic debris the fish manifests uneasiness, endeavors to leap out of the tank and shows oxygen hunger.

The writer wishes to acknowledge the able assistance of Mr. J. A. Kitson in conducting the field experiments.

# TABLE 1

## SYMPTOMS

| | INORGANIC ACIDS | | | ORGANIC ACIDS | | | ALKALIS | | | | SALTS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydrochloric Acid | Nitric Acid | Sulphuric Acid | Acetic Acid | Tannic Acid | Carbolic Acid | Ammonium Hydroxide | Potassium Hydroxide | Sodium Hydroxide | Arsenate of Lead | Calcium Hypochlorite | Copper Sulphate | Ferrous Sulphate | Mercuric Chloride | Potassium Permanganate |
| **1. Onset** | | | | | | | | | | | | | | | |
| **Rapid** | | + | | | | + | + | | | | + | + | | | |
| **Slow** | + | | + | + | + | | | + | + | + | | | + | + | + |
| **2. Irritation** | | | | | | | | | | | | | | | |
| **Restlessness** | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| **Rubbing movements** | | + | | | | + | | | | | + | | | | |
| **Secretion of mucus** | + | + | + | + | | | | + | + | | | | | | |
| **3. In activity** | | | | | | | | | | | | | | | |
| **Sluggish movements** | + | + | | + | + | + | | + | + | + | + | + | + | + | |
| **Lack of response to stimuli** | + | | + | + | | + | | | | | + | + | | | |
| **4. Swimming** | | | | | | | | | | | | | | | |
| **Rapid movements** | + | + | | | | | + | | | | + | + | | | + |
| **Irregular movements** | + | + | + | + | + | + | + | + | + | | + | + | | | |
| **Frenzied rushing and leaping** | | + | | | + | + | + | | | | + | | | | + |
| **5. Equilibrium** | | | | | | | | | | | | | | | |
| **Early loss** | | + | | | | + | + | | | | + | | | | |
| **Late loss** | + | | + | + | + | | | + | + | + | | + | + | + | + |
| **6. Respiration** | | | | | | | | | | | | | | | |
| **Increased** | | | | | + | + | | | | | + | + | | | + |
| **Decreased** | + | + | + | | | | + | + | + | + | | | | | |
| **Normal** | | | | + | | | | | | | | | + | + | |
| **7. Oxygen Hunger** | | | | | + | | + | + | + | | + | | | | |

## TABLE 2

### LETHAL DOSE OF CERTAIN CHEMICALS FOR FISH

| CHEMICAL | AUTHORITY | SPECIES | DILUTION | |
|---|---|---|---|---|
| | | | KILLED WITHIN 24 HOURS | NO EFFECT |
| I Inorganic Acids Hydrochloric | Belding | Brook trout | 100,000 | |
| | Clark & Adams | Carp, shiners, suckers | 274,000 | |
| | Marsh | Mummichogs, sunfish | 125,000* | |
| | Penny & Adams | Minnows, goldfish | | 50,000 |
| Nitric | Belding | Brook trout | 640,000 | |
| | Penny & Adams | Minnows, goldfish | 50,000* | |
| | Clark & Adams | Carp, goldfish, suckers, shiners | | 50,000<br>174,000 |
| Sulphuric | Belding | Brook trout | 160,000 | |
| | Penny & Adams | Minnows | 50,000* | |
| | | Goldfish | | 50,000 |
| | Wells | Blue-gill sunfish | 40,800 | 277,000 |
| | Marsh | Mummichogs and sunfish | 83,000* | |
| II Organic Acids Acetic | Belding | Brook trout | 20,000 | |
| | Penny & Adams | Minnows | 8,750 | |
| | | Goldfish | 3,500* | |
| Tannic | Belding | Brook trout | 160,000 | |
| | Penny & Adams | Minnows | 14,000* | |
| | | Goldfish | 7,000 | |
| Carbolic | Belding | Brook trout | 160,000 | |
| | Weigelt | Trout | 200,000* | |
| | Penny & Adams | Minnows | 70,000* | |
| | | Goldfish | 3,000* | 7,000 |
| III Alkalis Ammonium Hydroxide | Belding | Brook trout | 160,000 | |
| | Clark & Adams | Carp, shiners, suckers | 77,000* | 106,000 |
| | Weigelt | Small fish | 33,000* | |
| Potassium Hydroxide | Belding | Brook trout | 20,000 | |
| | Penny & Adams | Goldfish | 7,000* | 35,000 |
| | | Minnows | 35,000* | |
| | Wells | Blue-gill sunfish | 18,000 | 36,000 |
| Sodium Hydroxide | Belding | Brook trout | 40,000 | |
| | Clark & Adams | Carp, shiners, suckers | 14,000 | 18,000 |
| IV Salts Arsenate of Lead | Belding | Brook trout | 40,000 | |
| Calcium Hypochlorite | Belding | Brook trout | Over 100,000 | |
| | Mason | Trout | 2,000,000 | |
| | Waring | Tench | 200,000* | |
| | | Trout | 125,000* | |
| Copper Sulphate | Belding | Brook trout | 250,000 | |
| | Moore & Kellermann | Trout | | 7,000,000 |
| | | Black bass | | 500,000 |
| | Penny & Adams | Minnows, goldfish | 100,000* | 200,000 |
| Ferrous Sulphate | Belding | Brook trout | 7,500 | |
| | Clark & Adams | Carp, shiners, suckers | 157,000 | 200,000 |
| | Mason | Trout | 10,000 | 20,000 |
| | Penny & Adams | Minnows & goldfish | 10,000 | |

*Time not specified.

## TABLE 2 (Continued.)

### LETHAL DOSE OF CERTAIN CHEMICALS FOR FISH

| CHEMICAL | AUTHORITY | SPECIES | DILUTION: Killed within 24 hours | DILUTION: No effect |
|---|---|---|---|---|
| Mecuric Chloride | Belding | Brook trout | 80,000 | |
| | Mason | Trout | 20,000 | |
| Potassium Permanganate | Belding | Brook trout | 160,000 | |
| V Gases Hydrogen Sulfid | Belding | Carp | 160,000 | |
| | | Suckers | 263,000 | |
| | | Brook trout | 1,163,000 | |
| | | Goldfish, aquarium | 233,000 | |
| | | Goldfish, wild | 40,000 | |
| | Shelford | Carp | 300,000 | |
| VI Trade Wastes | | | | |
| | | Sunfish | 187,000 | |
| | | Trout | 100,000 | |
| | Weigelt | Tench | 10,000 | |
| Leather Board | Belding | Brook trout | 500 | |
| Paper Mill Sulphite liquor | Belding | Brook trout | 500 | |
| | Marsh | Perch & bass | | 200 |
| | Knight | Trout, perch, rock bass | 10 | |
| | Thomas | Trout | 750* | 3,000 |
| Wool Scouring | Belding | Brook trout | 1,000 | |

*Time not specified

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### *Discussion*

MR. J. B. DOZE (Kansas): Did I understand you to say that the action of copper sulphate on the perch and on the trout was similar, that the trout would stand more than the scaled fish?

DR. BELDING: I have only used it on trout and salmon. The figures which I gave on perch, bass, sunfish, etc., were furnished by Moore and Kellerman back in 1905; and I believe Marsh also has certain figures showing the variation of different species. In the case of perch the dilution was one and one-half millions, and Marsh claims that in the case of trout it should be seven millions.

MR. DOZE: Carp?

DR. BELDING: In the case of carp he gave three millions; but I will be perfectly frank and say that I question its correctness.

MR. DOZE: I was going to question that, because we sometimes kill carp with it when it does not affect the bass. I questioned that particular experiment.

DR. BELDING: It is not my work; I simply quoted it.

DR. FIELD: In experiments made with the State Board of Health of Massachusetts on Lake Massapoag for a determination of the quantities of copper sulphate, when one part to three million was used, I found that 550,000 white perch were killed right off the bat. That was the first thing it killed—and a very few bass, a very few suckers, and a very few pickerel, also a few shiners. The white perch was the least resistant of any of the species of fish in that pond.

PRESIDENT TITCOMB: My experience is that the bass is the most resistant of the warm water fishes we have here. The carp is quite sensitive. The northern pike is another very resistant species, much more so than the common pickerel, reticulatus. I wanted to ask Dr. Belding whether in these experiments he had a time limit as to the exposures of these fish in each case?

DR. BELDING: Twenty-four hours—everything is based on twenty-four hours. If you did not set a time limit, your results would be very variable.

PRESIDENT TITCOMB: You find that the effects of the copper sulphate in our largest natural lake, Bantam Lake, a comparatively shallow body of water, the maximum depth being only about twenty-eight feet, the copper sulphate had some action for a period of five days—very little, however, on the last day. I refer here to the clearing up of algae. Observations were taken daily, and it was found that during the first three days it was quite effective. I speak of that because I had got the impression that most of it was precipitated within twenty-four hours.

DR. FIELD: Another element to be taken into consideration in the use of copper sulphate is that the algae floating in the water, such as Anabaena, and so on, will first take up the copper sulphate, thus reduc-

ing the amount that reaches the fish and causes it to be in greater dilution than it would be if the water were clear.

PRESIDENT TITCOMB: If it is applied when the first stages of the algae begin to appear, a repetition of the dose may be avoided, and the algae is prevented from getting started so that it becomes very thick, as it does in certain waters of this state.

DR. BELDING: There are three factors that account for all these discrepancies. First, the water; because the conditions in it, such as mentioned by Dr. Field, and the chemical constituents differ, so that you cannot compare one body of water with another. Second, the species of fish vary in their resistance. Third, the method of administering the copper sulphate in the pond, whether it is distributed evenly so that the concentration is uniform and not more pronounced in certain parts of the pond than in others.

DR. DAVIS: In connection with Dr. Belding's results so far as tannic acid is concerned, the Bureau has had a rather interesting experience in one of its hatcheries, apparently due to that cause. At Hartsville, Massachusetts, for a number of years they have had very serious mortality among the brook trout fingerlings in the late winter or early spring. But that happens only in years when there is an excessively heavy rainfall, or when a warm spell comes on following a very heavy snowfall, in other words, when there is a good deal of surface water flowing into the hatchery supply. From further extended inquiry I am satisfied that the mortality among these trout only occurred since the chestnut blight. There was a hillside up above the hatchery which was covered with chestnut trees. Since the chestnut blight attacked the trees of course they have all died and the dead trees have fallen down on the hillside. As you know, chestnut bark is one of the richest in tannic acid, I think, of any of our native trees, and the evidence points rather conclusively to the fact that the tannic acid has got into the water carried down into the hatchery, thus resulting in mortality among the fish. Another interesting point there which coincides with Dr. Belding's experiment is the fact that the rainbow trout were not affected. The brook trout were almost entirely killed in several instances, while the rainbow trout were unaffected—fish of the same age, small fingerlings, still in the sac stage, and others which had been fed only two or three weeks.

DR. BELDING: Brown trout are even more resistant.

DR. DAVIS: There were none at this hatchery.

PRESIDENT TITCOMB: Dr. Stillman, in the survey down there where there was a cleaning out of the trout in one or two streams after the deforestation, was the chestnut a factor there?

DR. STILLMAN: Yes, it is a very common occurrence to find streams which have been devastated apparently affected by the acid from de-

caying tops. Oak and chestnut are the trees which seem usually to account for this condition, although we see a suggestion of organic pollution from such trees as produce the resins and oils, as, for instance, birch oil, but of course those trees are not so plentiful in lumbering operations. It would be very easy to pick out on a map a dozen streams that are not producing trout at the present time and where the cause seems to be entirely the organic acids from careless lumbering. Regulations and laws should be passed which would compel the lumbermen to clean up their tops after the cutting operations. It seems to affect all the fish life—possibly small pickerel less than other fish; but insect life suffers as well. I think that the blame is often laid on the removal of shade in those streams which fail after lumbering operations, when it is not always that; it is quite as often the organic pollution. Dr. Belding has shown what a small quantity of acid is necessary to poison water, and it must be remembered that when the streams are quite low in the summer we get a greater concentration of the acid in the water than when they are flowing strongly in the winter. I think most of the damage is done in ordinary lumbering under those conditions.

Mr. A. H. Dinsmore (Vermont): Several years ago we had some landlocked salmon in a raceway under a steep hillside that had been burned over thirty years before. On the hillside there is now quite a heavy vegetable mould from blueberry bushes and other shrubs that have grown up since the fire. In the summer time, when the weather was intensely warm, we had a cloudburst—I was in the West at the time but these are the facts as they came to me. Almost immediately following that, the salmon, among which we had suffered no loss before, began to die in large numbers. We moved them to other waters, but they all died. I was speaking of that to Dr. Davis on one occasion when he was at our place and he told me of a case where a cloudburst coming in very hot weather produced the same effect. He said it was thought to be due to absorption of oxygen in the water—the surface water running in rapidly and the heat of the ground absorbing the oxygen.

Dr. Davis: I have a number of instances on record of that sort of thing. Where there are very heavy rains during a hot spell, and there is also a great deal of debris and a large amount of organic matter washed in with the water, the supply of oxygen in the water is practically exhausted, and the resulting mortality has in many instances been laid to that. I do not believe that in any of these cases the cause has been actually demonstrated, but I have known of many cases where that would furnish a logical explanation.

Mr. Dinsmore: We made a bulkhead back of that raceway with lumber, thinking we would cut out the surplus water. Last summer we got one of these cloudbursts, and we had in a cement bulkhead, a square cement box that supplies this same raceway, probably four or

five hundred trout ranging from four to six inches in length. The water coming into this bulkhead came directly from a pond of about twenty acres. At the time the temperature was high, ranging around 68 to 70 degrees. The trout had made splendid growth all summer, with absolutely no loss. Below that were three or four thousand trout fingerlings, in the raceway where we had lost the salmon—trout that were then from one and a half to two inches long. This shower occurred in the afternoon, and immediately following it, remembering what Dr. Davis had told me, I rushed down to the bulkhead to see what the effect had been on the five hundred fish in the cement bulkhead. I may say that they were not getting any drainage direct from the hillside; they were getting it through a long, narrow neck at the outlet of the pond. The water was rushing down the hillside into this outlet of the pond and then going around into the cement bulkhead. It had been no more than thirty minutes, probably less than that, since the rain started, and there were at least forty dead trout in the bulkhead. Many more were on their backs, and the fish in the raceway below were just beginning to be affected. I jumped into the pond at the head of the cement outlet, dug away some dirt and threw a tremendous flow of the pond water over the surface of the pond, whereupon the fish righted and were all saved. I am sure we would have lost practically all the fish in that bulkhead but for the turning through immediately of the surface waters from the pond.

Mr. Powell: With reference to the chestnut blight, how long would it take the bark of the dead tree to affect the streams?

Dr. Stillman: We generally see no results the first year. In the cases I have noted personally, the deterioration begins the second year after the cut, and, according to the degree of pollution, it may last possibly six years. In one case I know of an eighteen year pollution, and it is still going on. Ordinarily, though, you can allow twelve to fourteen years to clear.

Mr. Powell: We have had this trouble in Maryland, but although the blight has been on for about seven years, it is just during the past three years that it has been affecting us.

Dr. Embody: Possibly what I am going to say was covered by Dr. Belding; if it was I beg his pardon. I just want to call attention to two or three conditions resulting from the treatment of a pond with copper sulphate. They have been brought out before; it is nothing new at all, but I think it is well to emphasize them at this time.

First, when you treat a pond with copper sulphate—and you treat it primarily, as I understand, to kill the excessive algae in the pond—you kill not only the algae but also a great many of the food organisms; you kill certain microcrustacea and a great many insects such as mayfly, nymphs, and some others. After these organisms are killed

their remains fall to the bottom and begin to decompose, in the process of which they use up the oxygen of the pond. So that you have not only the immediate effects of the copper sulphate but you also have the effects due to lack of oxygen in the pond. The way to overcome that, of course, is, after the treatment with copper sulphate, to run a good supply of water into the pond; you will then overcome that secondary reaction and have only the reaction due to the copper sulphate alone. In killing a large part of the food material or the forage in the pond you are doing something that the fish culturists would not want done, something that the owners of the pond would not want to see brought about in any pond they thought anything of.

Mr. Doze: What experiment would more nearly approach the toxic effect of leaf fall? We have a great leaf fall that kills a great many of our fish. Do you know of any quick remedy for that condition?

Dr. Belding: I do not know exactly what organic acids come from the leaves. I also do not know what the direct action of the acids would be. I do know that in certain of the ponds in Massachusetts in very warm weather, the organic acids and hydrogen-sulphide which are always present to a limited extent in nature, may become detrimental to fish life.

# THE NATURAL AND ARTIFICIAL FOODS OF FISHES

By Ida Mellen

*Aquarist, New York Aquarium*

"A fish eats fish," is a common slogan. It is the truth and nothing but the truth, but it is not the whole truth. There are many other items on a fish's bill of fare. Numerous examinations of the stomach contents have been made, as you know, by fisheries experts, and observers have set down their findings, so that we are able to say what is the natural food of many species. Aquarium experts and fish culturists know what substitutes fishes in general will accept in captivity. We even know that there are some foods they would never get in a state of nature, which they prefer to any natural foods you may offer them.

We are learning something new every day. Ichthyology still is so young a science that the longer we study fishes, the more deeply we are impressed by our hopeless ignorance of them. We have gathered but the beginnings of knowledge of their migrations, enemies, parasites and diseases, their reproductive and other habits, their natural foods, rate of growth, behavior, emotions, intelligence, and ways of living. We know just enough about fishes to be able to say with certainty that among no other group of animals is there such marked diversity in structure and form, in size, resistance, breeding habits, schooling and other instincts, and reaction to environment. In the matter of food, perhaps they vary a little less than in other respects, and yet the menu of the order ranges from diatoms to mammals. Diatoms are eaten by the mud-swallowing and plankton-consuming varieties, and others; and the mammals are mostly small ones such as muskrats, though sharks eat seals.

Sometimes we discover accidentally what choice in foods a fish may have. At the New York Aquarium we exhibit giant groupers—jewfishes. Many grunts and other fishes less than a foot long swim safely in the tank with these monsters. Last year our collecting boat brought in a brown shark two feet long, which was deposited in one of the jewfish tanks. A few minutes later it had disappeared. And so we acquired the knowledge that the jewfish has a weakness for sharks!

The question we are asking today is, On what does the food of fishes depend? Is it upon their size, their breeding habits, their schooling instincts and range, the shape of their mouths and teeth, the depth of the water they live in; or

upon vision, activity, or perchance the whims of individual or specific palate? Let us see, for if we can find this out, we shall know fishes at least a little better.

## SIZE.

As to size: the smallest of fishes are omnivorous, with a decided preference for animal food, among them the guppy (*Lebistes reticulatus*) and top minnow (*Heterandria formosa*). These have been maintained successfully in home aquaria without the introduction of food, being left to browse upon the filamentous algae that grow on glass and plants. They are fond of small invertebrates, such as water fleas and insect larvae and the minute fry of fishes including their own offspring; but in captivity they greedily accept minced raw clam and other shellfish, beef, boiled oatmeal, dried shrimp, and other substitutes. If a fish naturally is a cannibal, it never is too small to begin. In biology we say that the history of the individual recapitulates the history of the race. This would make it appear that originally all fishes were cannibals, for the fry of even non-cannibalistic parents instinctively prey on one another. Infant goldfishes and whitefishes require as careful sorting as any on this account.

When we consider the largest of fishes, the sharks, we find that although the group is notoriously fierce and bloodthirsty, some of its members are sluggish and inoffensive; among the peaceable sharks being numbered the nurse shark of Florida, with a maximum length of ten feet, and the whale shark of the Atlantic, Pacific and Indian oceans, which is the largest of all known fishes. The nurse shark is a bottom feeder, and the whale shark is pelagic. The whale shark, it is to be particularly noted, sustains its huge bulk of fifteen tons upon such foods as seaweed and plankton; in other words, plants and minute animals, for the most part invertebrates. It is evident, therefore, that size has little to do with the natural food of fishes, since we find such varied appetites in both large and small.

## BREEDING HABITS.

Nor do the breeding habits bear weight, for among the smallest of fishes we have both egg layers (nest builders and otherwise) and viviparous species—all having similar tastes; and among the fierce, carnivorous sharks, some lay their eggs loose and others in horny cases, while still others bring forth their young alive.

## RANGE, SCHOOLING INSTINCT AND ACTIVITY.

As to the range, schooling instinct and activity; the herrings have a wide range and school in the largest numbers. These active little fishes, and also the sardines, live on the same minute life of the sea that sustains the slow-moving, giant whale shark, which does not even appear to travel in pairs, for all we hear of have been found singly. On the other hand, the bluefish and common dogfish (horned dog) school and hunt in packs like wolves.

The range of the codfish, mackerel and sturgeon is as wide as the ocean. That is to say, they cross the Atlantic. What do they eat? The food of the mackerel consists of crustaceans and small fishes. The sturgeon eats algae, worms, mussels and little fishes. The things that a codfish will swallow remind me of an old nursery rime my mother used to read to me before I learned to read:

"What are little girls made of?
Sugar and spice and everything nice—
That's what little girls are made of.

What are little boys made of?
Scissors and snails and puppy dogs' tails—
That's what little boys are made of."

Scissors and snails and puppy dogs' tails—that's what codfishes are made of! Codfishes are all little boys. Not only scissors and snails and puppy dogs' tails tickle their palate, but jackknives, finger rings, oil cans, rubber dolls, books, boot heels, clothing and almost any sort of cast-off human trinket small enough to pass their throats. This shows how little the codfish worries about vitamines. It is not nearly as discriminating as we are when we dine on codfish steaks. Nevertheless, it has some choice items on its regular bill of fare. Irish moss, crabs, snails (as I told you), lobsters, starfishes and fishes, the eggs of the lumpsucker and other fishes. Here is a diet that seems to explain the rich flavor of codfish steaks.

But it is apparent that neither range, nor schooling instinct, nor activity, determine the exact nature of a fish's food.

## VISION.

How about vision? Well, in the matter of vision, the sight of some fishes is keener than others, though none can see far

through the water and pursue their prey over considerable distances only because they keep it in sight. Some also have a keener sense of smell than others, the nostrils being, of course, good for smelling and not for breathing; and a shark is said to be able to smell a flounder that it cannot see lying buried in the sand. Fishes that lose their sight still are able to find their foods, and those born blind get plenty to eat. The blindfish of Mammoth Cave, Kentucky, has an acute sense of touch and hearing. Its food is said to consist mainly of invertebrates.

Evidently vision is not the correct index to a fish's food.

### SHAPE OF MOUTH.

Surely the shape of a fish's mouth must have something to do with what it eats? We are inclined to settle this question immediately in the affirmative by saying, the down-turning mouth of the chub sucker shows its food to be what it gets by grubbing in the mud, and the prognathous snout of the mosquito fish, (*Gambusia*), shows that it is adapted to surface feeding. But as soon as we make comparisons, we meet with difficulties. The Remora has a prognathous snout, and it is not a surface feeder. It is fond of mollusks and crustaceans. The carps can turn their mouths down, but they feed as comfortably at the surface as at the bottom. Drums and cod, though bottom feeding fishes, do not have down-turning snouts.

The mud minnow (*Umbra pygmaea*), the bowfin (*Amia calva*) and the eel, all have blunt snouts and are voracious and cannibalistic. The bowfin can cut in halves at one bite a fish only slighter smaller than itself. But there is the whale shark, with a blunt snout, living on algae and plankton. The typical shark mouth is placed well under the snout, and the sharks hunt big game. But the sturgeon, with a mouth similarly placed, spends its time grubbing in the mud for little things, and the skates and rays are content with oysters and clams.

The shape of the mouth evidently does not settle the question.

### DEPTH OF THE WATER.

Has the depth of the water in which it lives something to do with the food of a fish? Yes, it has. Fishes that live at the surface necessarily are limited to surface foods—insects,

algae, plankton, little surface fishes, and in the ocean jelly fishes and the floating eggs and fry of fishes and other animals. They miss especially the molluscan and crustacean foods, and the worms that live in the mud of both fresh and salt waters; all to be found in the diet of those species that live at the bottom or descend to the bottom to feed. We know that fishes of the dark ocean depths are wholly carnivorous, since no plant life exists where they abound.

There are, however, such elements to be considered as whims of individual and specific palate.

### WHIMS OF INDIVIDUAL AND SPECIFIC PALATE.

Some goldfishes refuse any animal food, and some other vegetable feeders accept it willingly. If we visit Arabia or the South Sea Islands, we do not carry our Occidental cookery with us, but take things as we find them; and likewise a fish, transferred from native to foreign waters, will, as a rule, accept such food as is available, looking naturally for something that approximates its former menu. But a few are downright whimsical, and these are a grievance to the heart of aquarium folks, especially if they are species that the public clamors to see. The sea horses and their cousins, the pipe fishes, are the most worrisome boarders in the world.

Imagine a long-nosed gar, insisting that it will starve to death if you don't give it some live minnows; a sea horse fading away before your eyes because it will eat nothing but living minute animals—crustaceans, fry of fishes, tube worms, and such fare; or a pipe fish slowly shrinking to a dotted line because it will take nothing but water fleas and other actively moving, extremely minute invertebrates which would require your putting out to sea and getting a fresh lot of sea lettuce every day in the week, for it is in the sea lettuce that these tiny live creatures reside. All this spells whim. It's not only specific whim, but individual whim. I have found that some sea horses will take *Enchytraeus* and some will not; some like *Tubifex,* others won't look at it. Some will condescend to snap up a bloodworm or a young *Acellus;* others scorn such foods. And I have found that some pipefishes will spend hours snapping up little black aphids, while others would starve rather than touch an aphid.

And if it isn't the whims of the fishes, it's the whims of the public. People think it's frightfully wicked to put little fishes such as killies and roach into a tank for big fishes to swallow alive; but let them see a penguin diving for killies and

gobbling fifty at a meal, and they will tell you it was "too sweet for anything"; and to watch a couple of sea lions tearing apart a live eel: that gives them a thrill!

It shouldn't make anybody nervous to see a killi swallowed alive. But recently I saw an ocean trigger-fish making away with a large live crayfish, chewing it up inch by inch and sucking on the living tissues with the ecstacy of a child sucking on a lollypop. I assure you it was gruesome, and in feeding live food, I recommend that it be something that will be destroyed quickly. Incidentally, the trigger, in a state of nature, lives principally on barnacles, sponge shrimps, and other small invertebrates, and probably it seldom captures a molting lobster.

Now, so far in our inquiry we have found nothing that seems to determine what the nature of a fish's food shall be, except the depth of the water it inhabits. There is one thing, however, we have yet to consider. It is the teeth. Surely a fish's dentition must provide at least a partial index to its bill of fare?

## TEETH AND TONGUE.

We may guess that a fish like the great barracuda, with long, sharply pointed teeth (four of its fangs are one inch long) is prepared for tearing flesh: a vicious cannibal. And we find its reputation to be "fierce as a shark" and that it is not only a terror to its own kind, but has been killing human beings on occasion for three hundred years; never eating them, but merely biting deep into the tempting white flesh of bathers in southern seas. The bite, as a rule, severs an artery. We do not know whether one bite satisfies the fish's curiosity, or whether it fails to follow this up with slaughter because human flesh is not palatable to it.

The drumfish, with large, flat teeth so thickly and evenly set that its jaws appear to be paved with polished pebbles, is, we conclude, equipped for crushing hard shells. And we find that its food consists largely of crustaceans and snails, mussels and other mollusks.

The parrot fish's teeth puzzle one slightly. They are diamond-shaped and fitted together in the semi-circular head to form a beautiful, mosaic design, the little front ones like dolls' teeth, about six in a row on upper and lower jaw. Do the owners of this weak dentition subsist upon seaweeds, or perhaps soft sea worms? Their stomachs tell us that the coral reefs are their browsing grounds and the small, pretty teeth are superbly built to nip off the unsuspecting coral polyps as

they wave their tentacles gracefully in search of their own prey. "Life preys upon life"; yes, and beauty preys upon beauty.

In questioning the bearing of the shape of the mouth on the food, we may notice that the quiet, surface-feeding whale shark, with its blunt snout, has hundreds of pointed teeth, but they are extremely minute, while the blunt mouth of the voracious bowfin is a battery of teeth, some conical, some rasplike, some pointed and large. The grubbing sturgeon, with a mouth located beneath the snout, like a shark's, loses its first teeth and never cuts any more.

We begin to feel that we are on the right track. And I think we are, if we don't attempt making hard and fast rules. Fishes object to rules. There is, for example, the superficially confusing fact that surface-feeders have all kinds of teeth; little teeth like those of herrings and whale sharks, bony beaks like those of ocean sunfishes. And bottom feeders have mouths full of cobble-stone teeth like drumfishes, or cuneiform teeth both large and small as in the cod, or toothless jaws like sturgeons. The fact is, their feeding grounds are a matter of choice and habit, and they select their food from their feeding grounds according to their dentition.

Another fact is that fishes are as diversified in their dentition as they are in other respects. It would take a long time to describe every kind of tooth one can find in fishes. They have movable teeth, deciduous teeth, long and short teeth that are pointed or blunt, small mosaic or composite teeth, rasplike teeth, conical teeth, cuneiform teeth, oblique teeth, triangular teeth, and many other kinds. Some have bony beaks, some have only pharyngeal teeth, and some have no teeth at all. Pharyngeal teeth are of course used for masticating, the jaw teeth merely serving to capture the prey. Obviously we cannot classify every fish according to its teeth. We can only reach general conclusions.

Over a period of years, I have made a study of the foods of many species, correlating all the information I could find, and also making my own observations. Recently I have compiled tables showing the food with relation to the dentition of over one hundred kinds of fishes of both salt and fresh waters. Don't be alarmed. I'm not going to read the tables. I'm only going to give you a summary of them and of the conclusions reached to date regarding the proper foods generally for fishes held captive. I say to date, because this work is only just begun.

It may be appropriate to interpolate here that it is not apparent that the presence or absence of a tongue influences the nature of the food. Some carnivorous fishes have a tongue and some have not, and some herbivorous species have a tongue and others lack it. I am convinced that only the teeth and the depth of the water they inhabit, are important factors in their selection of foods.

Since I prepared this paper, Prof. Borodin has spoken to me of the importance of gill rakers. I have not had time to make comparative studies of foods with relation to gill rakers. In carp suckers, shad, buffalo fishes, menhaden, herring and such species, the gill rakers are generally long and slender, and in voracious species such as the bluefish and barracuda, they are short, or few, or altogether lacking. Among eaters of plankton, the gill rakers need to be fine for sifting the food. I hope that on the conclusion of my paper, Prof. Borodin will tell us something about his observations on the bearing of gill rakers upon food selection.

The majority of those whose food is known, have so-called villiform teeth, and next to these in number are fishes with so-called cardiform teeth. The villiform teeth may be conical, pointed or blunt, and may or may not be accompanied by canines. The cardiform teeth generally are closely set, as their names implies, but vary in size even in the same jaw, sometimes are in bands and patches, and often are accompanied by canines. As you might expect, both these groups eat about the same foods, but I will separate them for convenience.

Those with villiform teeth live principally on crustaceans and fish; fifty per cent. eat mollusks also, and forty-eight per cent. eat worms also. All the fresh-water kinds eat aquatic insects and algae and worms. They range in size from dwarfs to giants in both salt and fresh waters.

The silversides have simple villiform teeth in each jaw and a carnivorous appetite. The tarpon, with a mouth "hard as a stone," beset with small, villiform teeth everywhere, even to the base of the skull, dotes on mullet and hard-shelled crabs. Its cousin, the big-eyed herring or ten-pounder, preys on the big shrimp *Peneus*. In the pigfish or sailors' choice, the villiform teeth are in bands, supplemented by pointed pharyngeals. What does the pigfish eat? Not so much fish, but an abundance of crustaceans in the way of shrimps and other amphipods, blue crabs and young *Limulus*, flavoring its crustacean diet with razor clams and brittle stars and plenty of eel grass

and juicy ascidians and annelids. The pigfish, you see, is very selective. It may be a pig, but it has taste. We call it the sailor's choice, but it might well be called the dieticians' model.

In this group, also, in salt water, are the remora, bluefish, striped bass, croaker, black sea bass, kingfish, sculpins and snappers, all living on fish, crustaceans and mollusks, with an occasional worm. Fresh-water fishes in the group are the pike perch or wall-eyed pike, the sauger or sand pike, the pirate perch, miller's thumb, burbot or fresh-water cod, and many others. The pike perch, in addition to villiform bands of teeth, has sharp canines. Perhaps this explains why it adds to the regular fish and crustacean fare, such slippery animals as frogs and snakes. Here, too, are the yellow perch and small and large-mouthed basses. These basses differ markedly in other habits, as you know, the large-mouthed preferring warm, muddy waters and entering brackish and even salt water, while the small-mouthed favors a clear, cold stream; yet their feeding habits are not dissimilar. To the expected diet of fish, crayfish, algae, worms and aquatic insects, the large-mouthed bass adds to its festive board mussels, tadpoles and water rats.

Ninety per cent. of the little pirate perch's meals are made up of aquatic insects, while the miller's thumb divides its time between aquatic insects, crustaceans and fish, with an occasional special dessert of salmon and trout eggs.

Some fishes take their food gracefully and others are gormands. That is an individual trait and has nothing whatever to do with their dentition. The bluefish, with villiform teeth, gorges to the bursting point, disgorges and begins over again. The swordfish does the same stunt, without teeth but of course with the aid of its sword. We are interested today in what they eat, not how they eat it.

Now for the fishes with cardiform teeth. These include the angler and the pike tribe—pike, pickerel and muskallunge. Also the cod, the eel, and the American smelt. All is fish that comes to the nets of the pike tribe, snakes and frogs and other dainties included; and the angler is a study in itself. An old fisherman I once knew insisted that its scientific name, *Lophius piscatorius,* meant a loafer and a fisherman. Its taste ranges from starfish, sea worms and fish, to crabs, lobsters and birds. When angling becomes too much like loafing, the angler goes to the surface and exercises itself by dragging down a gull or a loon, or perhaps some ducks or geese. It is not adapted to captivity, unless one can provide it with small live fishes.

Summing up, then, fishes with cardiform teeth and villiform teeth live principally on fish and crustaceans, and some of them eat worms and mollusks, and other animals.

Let us spend a moment with the sharks and their allies, the skates and rays. Many sharks have triangular or oblique teeth, notched on the outer margin. Others have conical teeth, or their triangular teeth may be pointed.

Omitting the whale shark and the maneater, which I assume and hope none of us will have occasion to feed, a brief summary of the foods of sixteen kinds of sharks is as follows:

| | | |
|---|---|---|
| Fish | 35% | of the food |
| Crustaceans | 25% | of the food |
| Squids | 20% | of the food |
| Other mollusks | 10% | of the food |
| | or 30% | of mollusks |
| Seaweeds, sea worms, jellies, echinoderms and carrion | 10% | of the food. |

The preference for mollusks, you will observe, exceeds that for crustaceans.

Skates and rays are bottom feeders. Most of them have many series of small, paved or mosaic teeth, some conical, some pointed—all strong. They are among the few carnivorous species that prefer other foods to fish. This is the way their meals total:

| | | |
|---|---|---|
| Bivalve mollusks (mostly oysters and clams) | 50% | of the food |
| Crustaceans (consisting of shrimps and crabs) | 30% | of the food |
| Fish | 20% | of the food |

Let's take the fishes with bony beaks—boxfishes, puffers, and their allies. These live on crabs and sea urchins, oysters, scallops, clams and mussels, barnacles and sea snails, bottom fishes such as flounders, ascidians, worms, bryozoa and seaweeds. A varied diet, in which, as among the skates and rays, fish does not predominate. Yet they like fish well enough. I have seen a puffer take a perfectly round bite out of a small flounder, just as neatly as a cook cuts a biscuit out of a lump of dough. The ocean sunfish, with teeth of this kind, living at the surface, has nothing heavier to chew than jellies and Ulva, small crustaceans and little fishes such as elvers. In general, however, we may expect that fishes with

a strong bite will naturally take larger and tougher foods, and weak-toothed species will feed, as a rule, on weak animals. Those having sharp, pointed teeth, whether long or short or accompanied by canines, will be primarily tearers of flesh, and those with blunt teeth will favor foods that require crushing.

It seems doubtful if any fish is strictly herbivorous; and it seems somewhat doubtful, also, if many are strictly carnivorous, except deep-sea species.

Now, summing up, I have shown that

Sharks eat more fish than crustaceans, more crustaceans than cephalopods, and more cephalopeds than other mollusks.

Skates and Rays prefer oysters and clams to crustaceans, and they prefer crustaceans to fish.

Box Fishes and Puffers have a tooth for bivalves and univalves, crabs and urchins, flavored with worms and fish and seaweeds.

Tangs and doctors, pinfish, Bermuda chub, triggers and file fishes are called herbivorous because they are fond of fine seaweeds. But they are all very fond of fish and shellfish.

Fishes with no teeth, or with only pharyngeal teeth, include the carps and goldfishes and some of the catfishes, the pipefish, sea horse, shad and menhaden; and the adult sturgeon, whitefish and pompano. They all favor small invertebrates.

Grouping all other fresh-water species studied, the food sums up as follows:

Crustaceans, 21% of the food,
Fish, 20%; and fish eggs 5%; or 25% of fish and eggs,
Insect larvae, 16%
Aquatic worms, 10%
Mollusks and plants come next with each 9%, after which Beetles, mud, frogs, snakes and muskrats make up the remaining 10%.

Grouping all other salt water species, the food sums up as follows:

Fish 24%, fish eggs 3%, or 27% of fish and eggs,
Crustaceans, 23%
Mollusks, 19%
Sea worms, 12%
Echinoderms, 7%
Seaweeds, 6%
Miscellaneous invertebrates such as coelenterates and ascidians and so on, make up the remaining 6%.

And so we discover that the four principal food items in fresh water are crustaceans, fish, insect larvae and worms. The four principal items in salt water are fish, crustaceans, mollusks and worms.

Before drawing conclusions as to the best foods for fishes held captive, I wish to touch upon the foods now being used. Variety is the spice of our lives, and it is hard to believe that it is not also the spice of life for a fish. Goldfishes will eat more than thirty different kinds of foods; but, strange to say, the fishes that have lived longest in captivity are those that have had the least variety. One man tells me that among more than one hundred goldfishes, he has never had a sick or a dead one since feeding them exclusively on boiled spinach!

A goldfish was maintained for twenty-five years in a home in New York State, and passed from grandfather to grandchild. It was a male fish, kept first in a bowl, later in a six-gallon aquarium. At one time it had a mate and they produced two batches of fry. The fish never tasted anything but dry, prepared foods, with a very occasional earthworm. It moved about with the family, but always was kept in well or creek water, and finally died of old age, shrinking in size as very old animals do.

Goldfishes twenty-five years old on goldfish farms in the middle west measure two feet in length; but this goldfish, kept in a home aquarium for twenty-five years, measured only four inches. As far as longevity is concerned, food appears to be of secondary importance and we can hardly say too much about the quality of the water that fishes require. If we are what we eat, a fish, first of all, is what it drinks. We know from what Dr. Davis said last year that acidity and alkalinity are extremely important factors in fish life. Formerly we thought it was impossible to put too many plants in a balanced aquarium, except that they limit the swimming space. Now we know that there is such a thing as too many plants because of their tendency to promote alkalinity. Formerly we thought that nothing was more important than temperature. Now we know that some tropical species will adapt themselves to cold water, and of course the Bureau of Fisheries knows that, in captivity, it is higher oxygenation and not lower temperature that the northern species need.

I'm not following the hydrogen ion fad, but there are innumerable questions to be thrashed out with respect to acidity and alkalinity. I have half a dozen in mind at the present moment.

Referring again to goldfishes, of course they are no criteria in matters of food. Because they can live for a quarter of a century on dry foods, does not say that other species can do likewise. Recently, I have received an account of some brown and other trouts fed on whole dried shrimp. They had a lean and hungry look; their heads were bigger around than their bodies. A change to beef-heart spruced them up remarkably, and made sleek and round-bodied specimens of them. Even goldfish breeders will tell you that live food, such as Daphnia, affects the shape of a goldfish's fins and the depth of its color. At one goldfish farm the fry are fed on the roe of any kind of fish. It is split and laid on the bottom of the tanks and they help themselves. At the New York Aquarium we hatch no goldfishes, but only commercial fishes, and use Bureau of Fisheries methods, feeding herring roe, beef heart, and sometimes raw liver, all these foods being ground and then pressed through a strainer.

Let me give you a resumé of the foods used in public aquariums in this country and abroad.

## FOODS USED IN PUBLIC AQUARIUMS.

The New York Aquarium is the oldest and largest in the United States, and its general methods of feeding have been followed in some other American aquariums, with variations according to locality. We feed three times a week, using herring strips, chopped hard-shell clams and beef-heart for all fresh-water fishes, and herring, cod, clams, and latterly shelled market shrimp for salt water species. For species that require live food, we provide salt water killies (*Fundulus*) and pearl roach. This is the European rudd (*Scardinius erythropthalmus*), formerly very abundant in our park lakes. Sea horses and pipefishes have salt water *Gammarus*, when obtainable.

In the Boston Aquarium, cod, haddock and soft-shelled clams are used, a supply of *Fundulus* being kept for bass and pickerel.

The Fairmonut Park Aquarium in Philadelphia is lucky in the possession of a happy hunting ground for Daphnia, an ideal live food for small fishes, including sea horses.

At the Steinhart Aquarium in San Francisco, a fresh mash is used, composed of the following ingredients.

It is the outgrowth of various mashes, the manager of the Aquarium, Mr. Alvin Seale, having his men suggest improvements from time to time. The present mash of six in-

gredients was evolved from a mash of three ingredients, by Robert J. Lanier, a well known aquarist in his employ:

5 pounds of fish (flounders or herring),
3 pounds of beef-heart,
1 large head of lettuce,
2 cups of clams or mussels,
2 cups of rolled oats, and enough dried shrimp to make the mixture like dough when ground fine.

This mash is worth pondering over. It contains fish, mollusks and crustaceans, the three main foods of practically all fishes, besides the vitamines of fresh lettuce, cereals, and also beef, which most fishes are extremely fond of. The mash is fed to all the fishes and they thrive on it. Trout, in addition, receive bits of beef-heart and fish. Minnows, sand crabs and brine shrimps are used as live food, whenever obtainable. For fresh-water pigmies, the same mixture is used. If dried slowly in an oven, it will keep for a considerable time in Mason jars.

The Belle Isle Aquarium in Detroit depends largely on horse meat for carnivorous fishes, using cracked corn for carps.

The Lincoln Park Aquarium in Chicago uses largely beef-heart, liver and mussels, with shiners (*Notropis*) for live food when obtainable.

The Odenheimer Aquarium in New Orleans is most fortunately situated with respect to the use of fresh crustaceans. Mr. Schaumburg, the manager, writes so interestingly about this that I will quote from his letter:

"The Aquarium is only about two thousand feet from the bank of the Mississippi, and during nine months of the year the river is teeming with shrimp. Fishermen catch these shrimp for us and keep them in wire boxes until our regular feeding days, Wednesdays and Saturdays. Owing to the short distance to be transported, they are practically all alive when we feed. There is usually a number of small shrimp available for feed for the small mouthed fish; but for the buffalo, which do not like fish with shell, we peel and mash the shrimp.

"Of course large turtles, garfish, alligators, etc., are fed on larger fish, but as a general rule shrimp is the basis of our feed in the Aquarium.

"Have you ever tried oatmeal (Scotch Oats) for buffalo and German carp? We feed this regularly and they seem to enjoy it."

I'll say I have tried oatmeal for buffaloes and carps, and they simply flock around it. The omnivorous catfish, incidentally, is never too old or blasé to enjoy his Scotch—oats, I mean.

As you know, it is a general custom both in the United States and abroad, to feed pigmy fishes with *Daphnia* and *Enchytraeus*, alternated with dried ground shrimp. The Germans manufacture great quantities of artificial foods which are popular also in Holland, and some of which reach the United States.

In England, however, the case is different. Mr. Boulenger, the director of the London Aquarium, informs me that he uses no dry foods. Pigmy fishes there receive *Daphnia* and *Enchytraeus* throughout the year, the alligator pool in the reptile house having proved a fruitful breeding spot for Daphnia during the winter months. Three times a week nearly all the fishes receive horse's heart, which is much relished and easily digested. Even trout and marine species prefer the heart to prawns, *Gammarus* and mussels that are also fed them. Mr. Weller, the manager of the Brighton Aquarium, in England, which is the largest in the world, with 10,000 fishes to feed, against our 2,700 in the New York Aquarium, informs me that he uses live fish, live crustaceans, and dead fish. The small fishes of both salt and fresh water are fed on live sand-hoppers; the large fresh-water fishes and wrasse fishes receive live shrimps. Giant rays, monkfish and anglers are served with live flatfish. The dead fish used is whiting which is fileted and fed in chunks to sharks and all large sea fishes except those just mentioned.

Mr. Walter H. Chute, associate director of the proposed Shedd Aquarium in Chicago, who has recently visited European aquariums, tells me that at Berlin a great deal of lettuce is used for carps and other vegetable feeders. Fly traps are kept in operation in summer and live worms are used to a great extent. Beef is fed boiled, not raw as in this country. The water-fowl pond in the Zoological Garden supplies *Daphnia* even in winter, when it can be caught through the ice. On the Mediterranean, Mr. Chute says the aquariums use a lot of sardines. This I take to mean the aquariums at Naples, Monaco, Nice and Tunis.

## CONCLUSIONS AS TO THE BEST FOODS.

Now, if we consider the foods that fishes take in their native waters, and the foods they greedily accept and thrive on

in captivity, what shall we say is really best for them? Manifestly, we cannot give them precisely what they would have in a state of nature. Manifestly it never would have been possible to take them into captivity as we do and maintain them for years as we do, were they not so easily pleased with substitutes. Obviously, we should like to give them something approximating their natural food. One man was so imbued with this desire that he had mosquito larvae analyzed and then made up an artificial food to correspond. This mosquito compound consisted of one quart of wheat flour, one egg, one-third teaspoon of sugar, and one-fifth of a pint of lean boiled pork! Just how he managed to induce these singular ingredients to mix, is not set down; but he stated that the compound kept for a long time and was much appreciated. It was at least a change from ground puppy biscuit and dried flies.

Edwin Linton, the parasitologist, who has examined many hundreds of fishes, says "Annelids and crustaceans form the main food of fishes under 200 mm. long." This evidently refers to the young of salt water species and not to fishes of a maximum length of 200 mm., but it is interesting in view of the fact that breeders of fresh-water species feed their young fishes so successfully with *Enchytraeus* and *Daphnia*—worms and crustaceans.

Aside from young fishes and pigmy fishes, we have seven groups to consider: carps and other vegetable feeders; sturgeons, whitefishes and other eaters of invertebrates and fish eggs; skates and rays; sharks; boxfish and puffer and their kind; all others in fresh water, and all others in salt water.

I have already outlined the preferences of each of these groups. For adult goldfishes, the Japanese make a boiled mash of eighty parts wheat and twenty parts corn meal, with a dash of ground shrimp to flavor. This food, together with cracked corn and oatmeal and aquatic plants, would doubtless be acceptable to all suckers, quillbacks and buffalo fishes, catfishes, and cyprinodonts in general—carps, chubs, roach, dace and the rest.

In the case of other fishes, we are not all fortunate, like New Orleans, and our best method, no doubt, would be to feed with a mash similar to that used in San Francisco, adding whole mussels and other bivalves to the menu of the skates and rays, strips of fish or whole fish for the sharks, crayfishes for the larger fresh-water fishes such as basses, perch and pike perch, crabs or crayfishes and bivalves for the puffers and their allies, and crayfish also for some other salt water kinds such as

snappers, porgies, groupers and triggerfishes; and earthworms and roe for the smaller fresh-water species, seaweeds for such salt water kinds as will eat them, never overlooking the fondness of the majority for meat, which stands second only to live food in their estimation. Chopped clams and mussels may take the place of their molluscan foods, and beef-heart may be a rich substitute for aquatic worms. Personally I am a great believer in supplying small mouths with fish with the bone ground in. I have fed it to both turtles and fishes with most gratifying results. Every animal needs lime, and this is an ideal way to provide it.

I am inclined to believe, and would like to state provisionally that the size of fishes should govern our decision as to how often to feed them. Active fishes approximately one foot and under should probably be fed five times a week if they have ample swimming accommodations; fishes above that size, three times a week. In one of our smaller exhibition tanks, we have large morays. They want but one meal a week, and live for years. The pike, banded pickerel and eastern chain pickerel survive but two years in captivity on three meals a week, while a musky—like a big man who has always overeaten and finds himself immensely better when he cuts down on his bill of fare, will live for ten years on the same diet, and a striped bass or bony gar will live for twenty years on it. At the Boston Aquarium, puffers that were fed very often, actually bred in the tanks. On three meals a week, they last but a few months.

Crayfishes should be utilized. There are so many in this country that a despairing student once complained there is a different species in every mud puddle. Earthworms should be utilized for fresh-water fishes. This old planet is chock full of earthworms, you know. Of course salt water fishes do not care for them; they prefer sea worms, which are not so easy to get. Aquatic plants should be utilized. Enough aquatic plants are torn up and thrown away every year to feed all the fresh-water fishes in captivity. Mussels are to a fish what roast turkey is to us, and they are generally overlooked except that the fresh-water species are sometimes dried for little mouths. There are fifteen or twenty publications on the culture of small crustaceans as food for young salmonidae. Another thing, as you know, that young salmonidae are crazy about, and that all insect eaters—cyprinidae in general, sunfishes and other small species, are crazy about, is maggots, and nothing is easier to breed in fly time. A bit of meat

or, preferably, fish with the skin on, set out of doors, will acquire flies' eggs the same day and the maggots are hatched the day following, very tiny, almost microscopic. They grow prodigiously, and in a few days are half an inch long.

The value of live food for old and young simply cannot be overestimated. I wish all captive fishes could have live food. In some coastal regions, it is actually cheaper to buy killies by the bushel from fishermen than it is to buy beef and fish from the markets. The vertebrae, the fresh viscera and glandular secretions of live food, supply the needs of a fish's body for lime and other minerals, and for enzymes and other catalytic agents that aid digestion and keep the blood pure and the skin glossy; and no substitutes ever will equal live food. Live food will coax a sick fish to eat, and it will bring back the appetite of specimens that have gone on strike against regulation diet.

A fish's intellect may not be of a high order, but everyone here knows that it is higher than the fish generally gets credit for. The diversion and exercise of pursuing live prey stimulate its faculties and relieve the monotony of tank life. There is no fish so stupid that it does not feel its captivity, unless it was born captive. It is up to us to supply our fishes with satisfying meals.

### *Discussion*

PROF. N. BORODIN (New York): I have not very much to say with regard to the well prepared and very interesting paper submitted by Miss Mellen. I agree with her general conclusions on the significance of the dentition of fish in the choice and use of different foods. All the information Miss Mellen has furnished seems to relate to the adult fishes. The fish diet varies considerably with the age. Young carp, for instance, are unusually small crustacean eaters, while the adult carp eat some plant seeds and molluscs in great quantities.

I would like to make some remarks on the food of sturgeon, having principally in view the Russian species Acipenser Guldenstadtii Brandt and Acipenser Huso Pallas. They have no teeth, but they succeed very well in swallowing small gobins—several Caspian species of gobins which are bottom fish. The stomachs of the sturgeon are full of them, as well as with molluscs (Cardium). There is another item which enters into their diet, that is, the common bloodworm (larvae of Chyronomus).

In regard to the importance of gill rakers for selecting food, I might say that in the case of plankton eating fish, as for instance, Menhaden, Shad, Herring and Mackerel, the plants and animals of the plankton are so finely separated by a screen formed by the gill raker net, that

one glance at the stomach contents under the microscope might indicate to what fish it belongs. The microscopic diatoms are to be found only in the stomach of Menhaden, which has the finest gill raker net known. The shad has large openings between the gill rakers, and the mackerel has comparatively large ones, so that any microscopic crustaceans are retained by it. There are, however, exceptions to the rule. I found during the shad investigation in the State of Connecticut in 1924, in the stomach of a shad caught by the trap near the mouth of the Connecticut River, several yearling herrings.

MR. RADCLIFFE: As I listened to Miss Mellen's excellent paper I wished that I might send her an inquiry that the Bureau of Fisheries recently received. The inquiry was this: "Will you please furnish us with a list of fishes which under no circumstances will eat human flesh?" I am going to leave the answer to that question to Miss Mellen.

I can corroborate what Professor Borodin said about the shad. Ordinarily we do not think of the shad as being cannibalistic, yet I happen to know of instances where shad fry were planted in a pond under rather unfortunate circumstances—not a sufficient food supply—and at the end of the season when the pond was drawn down we had two classes of shad in that pond, a few ranging from around five, six and even seven inches in length, and a much larger group of pigmy shad which had not had much to eat. Now, it was wondered why there were the two classes. An examination of the stomach contents of the larger disclosed what had happened; they had been feeding on their less fortunate brothers and sisters and had thrived splendidly on them.

I was interested in some experiments or studies that were made with sea trout at Beaufort, North Carolina. Up to a certain length the food of the sea trout consisted practically wholly of crustacean forms, and when it passed that limit you found the menhaden entering into its diet. When it got a little larger, menhaden monopolized the diet to the exclusion of almost everything else. What happened apparently was this: that up to that stage, which, as I recall, was about twenty centimeters, the sea trout was too small to swallow the menhaden, but as soon as he reached the point where he could swallow the menhaden, then he began to eat them to the exclusion of almost everything else.

Studies of the feeding habits of sharks indicate that we will have to change our conception of their destructiveness of food fishes. As far as I can see there is no corroboration of that at all; I think that fish plays a much less important part in the food of shad and of sharks than is generally considered. An examination of stomach contents does indicate that they have a preference for members of their own family. I am wondering whether Miss Mellen could corroborate that.

MISS MELLEN: Yes, I think so. I think that practically all fish do prefer their own kind—I do not know why. They will prey on their

own eggs and fry and their younger brothers and sisters. Once at the New York aquarium a black bass attempted to swallow a bass only a little smaller than himself, and it took him three days to get the bass down. I believe that generally speaking they do prefer the members of their own tribes—I cannot say why. Bio-chemistry might answer that.

MR. RADCLIFFE: I would like that list of fishes that will not eat human beings—that under no circumstances will touch human flesh.

MISS MELLEN: I cannot say. I know there are many that could swallow human beings, but they do not care for us. I know that Zane Grey and others state that the manatee will eat human beings, but I am not sure that the manatee likes human beings as well as the shark does. But it is much easier to say which fishes are willing to eat human beings than to say which fishes are not. I know that the sharks do, and the giant manatee does, and that others will kill human beings even though they do not swallow them. But I think I should answer the question the other way round: I should give the names of those that will, not the names of those that won't. There are about 30,000 species to consider.

MR. VIOSCA: I would like to corroborate what Miss Mellen says with regard to the success of our New Orleans aquarium in relation to the accessibilty of the supply of river shrimp and other foods. I may say that we have a fish there which we have succeeded in raising in captivity, namely, the paddle-fish (*Polyodon spathula*)—an ambition which I think every aquarist has. I suggested that after making some examinations of its digestive tract: the gill raker is long and the stomach content enirely Copepods and small insect larvae. In captivity we have not succeded in preventing them from bringing their paddle into contact with the sides of the aquarium, and on account of that they are eventually lost. They are easily obtained, however, down there in small numbers and can be replaced. I suggested recently that instead of using hard sides on the aquarium we make a specially constructed aquarium for these fish, using sloping canvas so that the fish will not hurt its paddle.

There is one question I would like to ask: whether anyone here has made any observations on the use of the lateral line sense in fishes in connection with feeding or any other of their activities.

MISS MELLEN: I have not made any observations on that. I know that some fishes have no lateral line—swordfish, for example; but I am not prepared to say whether that has any effect whatever upon the selection of food.

MR. VIOSCA: After observing the activities of fishes in nature under almost every conceivable condition and trying to study their psychology, in nature and in angling, I have come to the conclusion that the lateral line sense of fishes is the most important sense they have, both in seeking their food and in escaping from their enemies, and so on. In some

fishes, of course, smell predominates, but where that is not the case I believe the lateral line sense is the most important sense they have. I intend to work that out and in two or three years I hope to present the result of my observations to the American Fisheries Society.

Dr. Belding: Miss Mellen referred to the question of the value of water. At the risk of starting an argument I would like to state my general feeling in regard to the question of the acidity or alkalinity of waters. In the Connecticut brook trout streams I found that apparently the pH value made little difference; good brook trout streams were found with a pH of 5.4, and also up to a pH of 8.4. Apparently the trout did as well in the acid streams as it did in the alkaline streams within those limits. The character of the country determined the question of alkalinity or acidity to a greater or less extent in those streams. For instance, the limestone region gave the 8.4 streams, and they were perfectly good trout streams. Also from observations in connection with anadromous fishes, those that come from the salt water to the fresh to spawn, and also because of the work of others I have in mind—Brown and Jewell, where they changed the fish from an acid lake to an alkaline lake, and vice versa, without any apparent discomfort or adverse effect upon the fish, I feel that the importance of the pH value with regard to fish waters is perhaps overestimated. The acid reactions I showed in the table in the previous paper brought it down below pH 4, so that I think we can exclude the question of pH value as directly influencing fish life to any marked extent. I know other people will differ with me on that point, but that is my view.

Miss Mellen: Recently in Cleveland the Independence Nursery Companies exhibited some tropical toy fishes; some very delicate species were exhibited there. One tank of Brazilian half-moons (*Scalare*) began to develop tail rot, fringed fins and tail. The chemist employed by the people who exhibited the fish introduced hydrochloric acid into the water, after testing it and finding that it was too alkaline, and the fishes began to show improvement within twenty-four hours and were all well in two days.

Then again, I would like to say, in regard to salt water fishes, that for many years at the New York aquarium we have been using the same salt water—the same water was used for seven consecutive years without any addition; we have a closed circulation. After a number of years we would add some water to replace that which had been lost through evaporation and seepage. Our fishes about six months ago developed sore spots, a great many of them. I think this subject should be exemplified more with relation to species, because some require more of an acid and some more of an alkaline condition. I believe that most fresh water fishes require an acid condition and most salt water fishes, if not all, require an alkaline condition. While I was able to treat the

smaller fishes for their sore spots I could not handle a 250 pound jewfish which had sore spots the size of a silver dollar all over its body. But recently we replaced that sea water which we had been using for many years with sea water brought in from forty miles off the coast of Maine, and within twenty-four hours the spots had all disappeared from the giant grouper, the big jewfish which I could not handle. So it seems there is a little truth in this theory. I am not prepared to say how much; I have not worked very much with it.

MR. GREELEY: I would like to ask Miss Mellen what distinction she has made between the sense of smell in fishes and the sense of taste. For instance, in fish like the spotted cat fish, which has barbels, I understand the histology shows that there are what practically amount to taste buds on these barbels, and I think the same is true of the German carp. In that case the taste buds are not found on barbels but extend over a good bit of the head. The spotted catfish can find food in very muddy water. Do you think it is really taste in fishes or smell that enables them to find their food?

MISS MELLEN: As far as I know there are only a few fishes that have a strong sense of smell, and that therefore the taste is probably the more important of the two. I have seen some fishes, goldfishes notably, that were offered food that looked something like they were accustomed to enjoy, and when they found it was not that food, and they did not like it, they spat it out. Then they would go away from that particular place and would not show up again; if they saw anybody coming they would go away, showing their strong disapproval of a food that did not taste as they expected it would. So I rather think that taste is more important than smell.

PRESIDENT TITCOMB: I would like to inquire whether the muskellunge shed their teeth.

MISS MELLEN: I really do not know.

PRESIDENT TITCOMB: Do they become soft and loose?

MISS MELLEN: I really do not know.

PRESIDENT TITCOMB: Do you think salt water mussels are suitable food for trout?

MISS MELLEN: Generally speaking fishes in fresh water require food that has grown in fresh water, and those in salt water require food that has grown in salt water, although we feed salt water clams to all our fresh water fishes. Therefore I see no reason why you should not use salt water mussels.

MR. DEROCHER: Do you use salt water mussels to feed any of the salmonoid family?

MISS MELLEN: No.

MR. DEROCHER: In Scotland all trouts are fed salt water mussels, especially when they are breeding. That is a special food.

DR. DAVIS: I do not want to start any discussion here, but I wish someone would explain the difference between taste and smell in fishes.

MR. GREELEY: The sense of smell of fishes is located largely in the nostrils, and the sense of taste—I am sorry I do not know more about the structure of the taste buds, but the sense of taste is not located in the nostrils; it is located in fine taste cells which may, as I understand it, be in a good many places. That is, in some fish they are not restricted to the inside of the mouth as they are in humans.

MISS MELLEN: I should say that irrespective of where they are located, the taste probably corresponds in some measure to our own.

MR. LAIRD: In the feeding of any of the molluscs—clams, scallops—are you ever bothered with worms of any kind? Do you have any trouble afterwards with gill worm?

MISS MELLEN: We have had infestations of trematode worms, but we were not able to explain it. Possibly that does explain it. Some angel fishes, for example, that we brought up from Key West almost a year ago mysteriously developed flukes in the gills in the spring time. Where they came from nobody could imagine; they had been in the tanks all along. Possibly it was in the gills when they were brought up and as this was their breeding time, they were just developing. We had the same thing happen in all of our trouts—brown, brook and rainbow; they suddenly developed trematode of some nature.

MR. LAIRD: Two years ago I was experimenting with the feeding of scallops. I am sorry I did, because I think I got a lot of gill worm as a result, and I have had a lot of trouble since along that line.

MISS MELLEN: I consider that a very interesting point.

MR. GRAHAM: I would like to inquire whether in your feeding experiments, especially with brook trout, you have ever noticed any difference in the length of the gill covers that different foods produced. I heard you mention gill rakers.

MISS MELLEN: No, I never made any observations on that point.

# ARTIFICIAL PRODUCTION OF FOOD FOR YOUNG BASS

CHARLES O. HAYFORD.

The papers of Lydell, Baldwin, and Snyder at last year's meeting, and the discussions thereon, covered practically all these questions with regard to bass food, except this new Daphnia magna which is now being passed around. It is the largest type of Daphnia I know of. Dr. Embody and I have been constantly experimenting with food for young pond fish and I do not hesitate in saying that with us the Daphnia magna gives the best results and can be produced in the greatest quantities of any aquatic insects we have experimented with. You will notice from the sample that there are Daphnia small enough, from the young up to the large, to feed almost any size bass and bluegills up to three or four inches in length.

We produce this Daphnia in concrete ponds five feet wide, thirty feet long and two feet deep. We take about twenty quarts of solid green cow manure, and mix it up in an ash can of water, adding four quarts of menhaden meal and four quarts of bean meal. This works out very well, and it is about the cheapest material we can get. There are many other materials that will produce Daphnia, such as sardine meal, green bone meal fertilizer, decayed fish, and cooked oatmeal. Horse manure is good, but it is not equal to the cow manure.

The great advantage of the Daphnia magna is that it hatches at least four weeks earlier than the other Daphnia. In fact, during the winter if the weather becomes warm enough to melt the ice from the Daphnia ponds and remains warm for three or four days one can notice a large hatch of the young magna; however they do not grow as large in the low temperature as they do in the higher temperature of the summer months. The least covering of ice on the ponds immediately drives the Daphnia to the bottom where they remain dormant. We have experimented quite extensively with our glass perch jars with this Daphnia during the winter and are satisfied that large quantities can be raised for feeding young trout, if the hatchery has lots of glass to admit sunlight. We know the young trout eat the Daphnia readily but we have not carried on any tests as to the food value for young trout.

We get by far the greatest success in hatching the Daphnia in separate ponds and seining them out with fine nets made of bolting cloth. The expense of handling is very small. Last

year four of our boys sprinkled enough Daphnia through the ponds to feed 200,000 two to four inch bass, 600,000 one to two inch bluegill sunfish and 100,000 golden minnow fry.

This Daphnia is readily taken by the small and large mouth bass, minnow fry, young perch and bluegill sunfish. Its greatest value of course is for feeding the small mouth bass. We raised 26,000 two-inch small mouth bass fingerlings on this daphnia in a test pond one-third of an acre in size. The little small mouth bass became so domesticated that when anyone appeared around the pond with a pail they would collect in large schools waiting for something to eat.

It is not an uncommon thing to see the bass breeders feeding on this Daphnia when it is collected in large schools. Our difficulty in the past was to produce sufficient food to raise the bass up to the two-inch stage. After they reach this stage we have no difficulty in feeding them on chopped sheep hearts.

In our pond system, the water falls nineteen feet from the first reservoir to where it leaves the property. The bass ponds are laid out in two sections. Each section now has eight ponds; when completed each section will have twelve ponds of about one acre each. There is a ten-inch pipe of water supplying each of these sections. All ponds can be drained absolutely dry and any one pond can be drained while the balance is in operation.

The golden shiners I talked about yesterday also go along with this system of feeding young bass. We can raise these shiners by the million and feed them by the method we use in bass and blue-gill propagation. After they attain a size of one inch these shiners eat chopped meats very readily.

In one of the ponds last spring we had a surplus of male bass; when we seined the big reservoir we picked out enough females to go with them. You cannot have the domesticated males and wild females together. In the ponds where we had domesticated males and domesticated females we got a fine hatch and had good luck, but in the two ponds where we had the wild females we got nothing; they ruined the whole works.

### *Discussion*

Mr. Radcliffe: A little occurrence in our aquarium at Washington rather interested me in this connection. We had in one of our aquaria about a dozen small-mouthed bass. Late in May they decided to spawn there. After the first brood appeared we took the adults out. Cannibalism started in almost immediately. So we removed about 2,500 of the young fish to a pond, leaving about 100 in the aquarium. Later on

in the other aquarium to which we had transferred the adult bass, a second brood of young small-mouthed bass appeared, and again we took away the adults. Cannibalism started with these small-mouthed bass almost from birth. So we got a supply of Daphnia from nearby pools and started feeding those in the aquaria. Incidentally we put one charge of Daphia in this first aquaria where the one hundred or so small-mouthed were still kept. I do not know what happened; the only way I can figure it was that among the Daphnia there was a large-mouthed bass, no larger or a little larger than the one hundred small-mouthed bass in that aquarium. No more attention was paid to that aquarium in the way of feeding for four weeks, and during that time the large-mouthed bass consumed the one hundred small-mouthed bass that were in there with him. But we noticed that just as soon as we introduced the Daphnia into this newly hatched brood No. 2, all cannibalism stopped. Up to that time you could at any time see three or four bass with some unfortunate brother or sister engulfed, with perhaps only his tail sticking out. We carried them along perhaps two or three weeks until they reached a large size; then, cannibalism again began to appear. I was wondering whether Mr. Hayford could throw any light on that—as to whether when they get beyond a certain stage or a certain size they prefer some other food than Daphnia.

Mr. Hayford: There is much more cannibalism among the wild breeders than there is with the domesticated ones. It takes us about the first season to get the wild bass breeders to eat properly. Some of them never get tame enough to take artificial food. With baby bass up to an inch or an inch and a quarter long we did not have much trouble with cannibalism but we found that quite a few of the bass from an inch and a half to two or three inches long were absolutely destroying the little ones.

Mr. H. W. Beaman (Connecticut): I have been engaged in the propagation of small-mouthed black bass for a period of twenty-six years, and during that time I have had about all the experiences it is possible to have with these fish. When the fry first rise from the nest they have consumed all that nature has provided them in the egg sac, and they are ready to take food through the mouth; if they are not supplied with the proper food they will begin cannibalism. At my hatchery we begin feeding immediately after the fry rise from the nest, making available to them a supply of crustacea. We are not obliged at our hatchery to cultivate the crustacea as Mr. Hayford has described. We go into Lake Waramaug, where our hatchery is located, and obtain them in quantities sufficient to feed our bass. We have nets specially devised for this, made of a grade of cotton cloth which will strain the water but retain the crustacea. These nets are trailed behind the boats, and when sufficient crustacea have been gathered they are drawn up

and emptied into a pail. When we have a sufficient quantity on board the boat, it is taken in and placed directly in the tanks, and the fish immediately begin to feed on it. The thing is to keep your water well supplied with the minute crustacea, all that the bass will feed on, and as long as they have that there will be no cannibalism, except when they come to the period which we term the advanced fry period, when they seem to prefer larger forms of food than the crustacea; the crustacea does not seem to satisfy them. It is then that we plant them; we consider that they are ready to take care of themselves. In fact they develop that wily, secretive habit which is peculiar to small-mouthed black bass in the highest degree when they reach the advanced fry stage. That stage compares with the protection the fish receive in the wild state from the parent fish; in other words, the male bass will protect the school until they have reached that stage where they desire larger forms of food, and then the school scatters. We have attempted to carry these bass beyond that stage in our tanks, but the result has not been favorable. It seems to be their nature that they should scatter; we believe we get better results by putting these fish out at the advanced fry stage in their wild state. But we are very careful to plant them along the rocky shores and shallow waters where they can get cover among the stones, which is exactly what they would find in the wild state. Our plants of these advanced fry have given splendid results. We have raised them up to fingerlings, but we consider that they are more valuable at the advanced fry stage for stocking purposes than they are at fingerling sizes.

So far as cannibalism is concerned it is a matter of keeping your fish well fed and not carrying them in large numbers beyond the stage in which you can supply them with the proper food.

In the early stages of this work we attempted to feed them artificially, and succeeded. We fed them on ground-up fish. We had the same experience that Mr. Hayford has recited here in teaching them to feed. I worked over them day after day, and occasionally I would get one to take a little food artificially, and the moment they got a taste of it they were voracious and took it readily enough. In two or three days you could see a marked change in their appearance, but those that failed to take the artificial food became very thin. So that we had to go back to the crustacea in feeding those that were weak, and when we had them braced up we started in with the other type of food, this ground fish. In a few days we would get another lot, and we would keep them worked up until we got the whole lot feeding, and after that there was no trouble; they grew well and made splendid fish.

In the early part of our experience we stocked one of our ponds at the hatchery with 10,000 fry which we had brought to the advanced fry stage, and about six weeks later we took about 250 two and a half to three inch fish out of that pond. In other words, it took 10,000 bass to

produce from 150 to 200 fingerlings, so we came to the conclusion that it did not pay to try to raise fingerlings. All our fish are now shipped when they have reached the advanced fry stage.

MR. POWELL: This year some Daphnia were introduced in our part of the country, and we tried to raise them on dirt bottom ponds. We got the first culture all right, but the second culture seeemd to have what we thought was fungus on it. Each generation then decreased in size, until now the adult is not as large as our native Daphnia. I was wondering if anybody ever tried raising them in dirt ponds, and if the kind of water has anything to do with it. We use creek water, and I notice that where they are raised successfully, spring water is used.

MR. HAYFORD: We produce the daphnia in both dirt and concrete ponds with great success—we get a lot of them twice the size of those you see here. When we got the smaller ones at the start, Dr. Davis said we were not polluting our water enough, so we increased the fertilization. Do you keep your ponds dead?

MR. POWELL: Yes.

MR. HAYFORD: By selective breeding—picking out the largest and best daphnia for breeders, the size of the stock is continually increased. By using a net with the right size mesh you can seine out the largest Daphnia leaving the smaller ones to reach maturity. You did not get any other type of Daphnia with them, did you?

MR. POWELL: No.

MR. HAYFORD: Of course in resetting the ponds we try to keep them as near a pure culture as we can.

MR. POWELL: Would the natural creek water make any difference?

MR. HAYFORD: I do not know that it would. Of course I think it is better to use spring water. If you use creek water you are getting other types of Daphnia. For that reason we use spring water.

MR. JOHNSON: I would like to ask Mr. Hayford if he thinks that in the case of very small lakes near cities where there are more fishermen than fish it might be worth while to add Daphnia culture and possibly later chopped meat to their natural food? Would that increase the yield of adult fish enough to justify the extra expense?

MR. HAYFORD: I would say generally that the greater the variety of food of course the better it is for them. It has been my experience that if you can feed the bass on natural food you do not have much trouble.

MR. LORD: With regard to the use of forage minnows to keep down cannibalism when a diet of Daphnia is found to be insufficient, I may say that at Fairport last summer we had two ponds, both equally well stocked with Daphnia. In one, golden shiners were very abundant; in another there were hardly any. When these ponds were drained in the fall, the pond stocked with an abundance of golden shiners produced bass wonderfully uniform in size—four and a half inches—while the pond

lacking an abundance of shiners produced bass from two to eight inches. This was clear evidence of cannibalism. The bass well supplied with forage minnows had an equal chance to make an excellent uniform growth, none of them being capable of eating any of the other bass; the others turned to feeding upon one another, the larger becoming still larger and the smaller growing only half as large as those which had access to the shiners. Daphnia can thus be followed by forage minnows, and an excellent uniform growth and low mortality from cannibalism will result.

DR. DAVIS: In connection with the experiment at Fairport to which Mr. Lord refers, in the pond in which we had the forage minnows the loss from cannibalism throughout the summer was only about eighty per cent, which was considerably better than some of the others had been getting judging from the remarks I have heard here. These ponds were, I considered, overstocked with bass fry also. These were large-mouthed fry which were held in the ponds throughout the summer; they were drained in the latter part of September or October, and there was quite a noticeable difference in the mortality, or the loss—of course it was almost entirely due to cannibalism—in the ponds which had forage fish and those which did not contain forage fish. The differential was very marked in favor of ponds containing the forage fish.

DR. EMBODY: I just wanted to mention how these Daphnia happened to have been used—how we came by them. A year ago last spring Dr. A. Barker Klugh, Professor of Zoology at Queen's University, Canada, came down to us to do a little graduate work. He had previously worked on the feeding habits and reproductive habits, and so on, of various Daphnia and other entomocostraca, and he happened to mention to me that he had succeeded in raising this Daphnia magna in indoor cultures. So I asked him if he would not have a few sent down to me. He did, so, and when they arrived there were just six individuals alive. We took those six individuals, put them in separate containers, selected them individually and from those this culture has come. Even further selection than that was made. The progeny from these six individuals were also isolated in about twenty-five or thirty different containers; tabs were kept upon the reproductive capacity of them, the rate of growth and so on, and selection was made of those that showed the highest reproductive capacity. All that Mr. Hayford has, and has had distributed, and all that we have, have come from these, so that it is really the result of selective breeding. The Daphnia lays two types of eggs, one type which is not fertilized, the parthogenetic, a summer egg, and then the so-called winter egg, which is developed at different times during the year. It comes when the food gives out; it comes just before a drouth is going to take place; it comes from different causes throughout the summer. They invariably lay a large number of these winter eggs in the fall, and they also lay them if the food gives out. In this culture

if you do not feed fertilizer to them at frequent intervals they will begin to lay the winter eggs, and that means the end of your culture, because the great majority of them die after the winter eggs are laid. These winter eggs, I may say, can be dried out; they can be frozen and they will hatch out the following spring. The ponds in which we keep these cultures are regularly drained in the fall—they are concrete ponds, and we usually put in straw and manure to prevent the frost from injuring the concrete walls and to keep them dry throughout the winter. They are refilled about the first of April, and about the first week in May we begin to get these Daphina. After they appear it is an easy matter to keep them going all summer long by frequent additions of fertilizer. Our concrete ponds are absolutely tight; there is no seepage whatsoever; the water is absolutely stagnant—no current going through. We secure the best, the most constant and the surest results from the use of dried sheep manure, added at the rate of about one quart for every twenty-five cubic feet of water. Now, you have quite a range there; you can get a culture with a pint to twenty-five cubic feet of water or with two quarts of manure to twenty-five cubic feet of water. Under similar conditions other cultures might be lost; if you put too much manure in, it pollutes the water to such an extent that they are all killed.

PROFESSOR BORODIN: Dried manure is used in Europe for that purpose.

DR. EMBODY: In this connection I may say that these Daphnia require a certain amount of lime, and we found that where an earth bottom was used we had to add some lime. We use ordinary bone meal. We use bone meal and sheep manure because it is a product that we can buy at the florist's; it does not vary much in its composition, and it seems to give uniform results. You can get just as good results from horse manure or cow manure, and undoubtedly from a proper selection of fish meals, straw or hay—ordinary hay will produce this culture, although of course the results will not be as satisfactory from the point of view of density of numbers as you secure when you use manures properly supplied with calcium. In the concrete ponds the calcium in the concrete is sufficient to furnish what is needed, so it is only necessary to add the manure itself.

# THE FRESH-WATER SHRIMP FOR REPLENISHING FOOD IN TROUT STREAMS

BY JOHN W. TITCOMB.

It is generally recognized that trout under natural conditions take the kind of food which comes to them and take it in great variety. When shrimp predominate in food available they take shrimp, and the more successful the introduction of shrimp the more favorable the conditions of such streams for increased trout production. The indiscriminate planting of shrimp in waters where conditions are not known, and consequent failure results, creates an unfavorable impression on the mind of the layman angler, if he has been led to believe that the annual purchase of thousands of shrimp is going to create a transformation in the condition of his trout waters.

Much has been written on fresh water shrimp. It has been a subject for discussion in earlier publications of this society. *Embody, a member of the society, has very fully covered the activities of the fresh water shrimp as to known distribution, food and reproductive capacity. **Kendall, also a member of the society, has added to our knowledge of these crustacea and discussed quite fully the possibilities of their use in fish cultural establishments. The subject has not been treated by either of them with reference to the quality of the water requisite to habitat.

This paper discusses two species of Amphipods common to Connecticut waters, viz.—Gammarus fasciatus and Hyalella knickerbockeri; also the Gammarus limnaeus or Caledonia shrimp which, as investigation shows, is not found in Connecticut waters.

The Caledonia shrimp derives its name from a stream having its origin in the village of Caledonia, N . Y. Near the source of this stream is located a trout hatchery, (now operated by the State of New York) which, in the early days, was established and operated by the famed fish culturist Seth Green, one of the pioneer members of this society. In one of his addresses before the society (1875) he remarked: "The great secret in this work is in putting fish in the waters suited to them." It is intended to show that this statement is equally true as applied to shrimp.

*A Preliminary Study of the Distribution, Food and Reproductive Capacity of some fresh-water Amphipods by George C. Embody.

**Fresh-water Crustacea as Food for Young Fishes by William C. Kendall. (Bureau of Fisheries Document No. 914).

Another distinguished pioneer member of this society from Caledonia, and successor to Seth Green, was James Annin, Jr., who subsequently established a commerical trout hatchery above the State Hatchery, on the same stream, now operated in the name of James Annin & Sons. From this source millions of shrimp have been distributed for stocking trout waters in various parts of the country.

The question has often been raised, did these shrimp produce satisfatcory results and have the distributions been intelligently made?

Through the courtesy of Mr. H. K. Annin of Caledonia, N. Y., who deals in the Caledonia shrimp, the addresses of ten customers were furnished.

A circular letter was sent to these customers explaining the object of the inquiry. Six replies were received. With one exception the replies indicated failure. In one instance the results were doubtful. One inquiry was referred to Professor Reighard as he had surveyed the waters in which the shrimp were introduced, Loon Lake Gogebic Co., Michigan. Reighard informed the owner that shrimp require limestone water and warned that further attempts at introduction are useless. He found the water "practically free from carbonates and quite acid (pH 6.4) : there were no molluscs or crawfish and practically no vegetation."

So far as is known, Reighard is the only biologist to state definitely that shrimp require limestone water. It is natural to assume that he had in mind only the species of fish cultural fame from Caledonia, N. Y.

Experienced fish culturists have for some time felt that the use of shrimp as a means of increasing trout food is being overdone. Some have entertained the idea that shrimp thrive only in hard water. Shrimp, in the language of the fish culturist, has almost invariably meant Gammarus limnaeus. It is the species which has been generally advocated for stocking trout streams, without previous knowledge of the water to be stocked, other than that the temperature must be suitable for trout, and that vegetation is desirable.

The matter was focused in the mind of the writer when the failure of two attempts to introduce the Caledonia shrimp, G. limnaeus, in the water supply at the State Trout Hatchery, Burlington, Connecticut, indicated that there ought to be some way of ascertaining the nature of waters in which shrimp thrive or do not thrive. The water at Burlington has a temperature ranging from 50° to 55°. Where the shrimp were introduced there is a profuse growth of vegetation. Conditions

conform to those described by Embody and Kendall as favorable for shrimp.

This inquiry is therefore concerned with the kind of waters in which the fresh water shrimp thrive as compared with the waters in which they do not appear to find a congenial habitat. In other words, if some waters lack the essential elements to support shrimp, what are those elements and how are they most easily determined?

In order to ascertain whether the water is the determining factor in the habitat of shrimp, samples were produced from sources where one or more of the larger species of shrimp are known to abound, and analyses of such waters were obtained. An analysis of the hatchery water, in which the introduced shrimp disappeared, was also obtained.

Some years ago the writer had the pleasure of visiting the hatchery of William H. Rowe at West Buxton, Maine, and at that time found the waters teeming with shrimp that were assumed to be G. limnaeus. Samples of shrimp and water were furnished by Mr. Rowe.

The shrimp from Mr. Rowe's hatchery proved to be G. fasciatus from soft water, but in such abundance as to produce an increase in trout food as favorable as the G. limnaeus produces in the harder waters of the stream at Caledonia.

There will be no dispute among fish culturists as to the value of shrimp as a trout food. When Mr. Rowe established his hatchery at West Buxton, Maine, and these shrimp-inhabited waters were stocked with trout, the latter developed a beautiful pink flesh and the eggs of these trout when they matured were also very highly colored.

The hatchery reared trout introduced as adults to cranberry bog ponds down on Cape Cod assume the color of wild trout in the course of a few weeks, as stated by Mr. L. B. Handy who controls the fishing rights on these ponds, and in an almost incredibly short time these fish become beautifully marked and attain a high color of flesh, which color is attributed to the shrimp G. fasciatus of that region.

At the Gilbert Trout Hatchery in Plymouth, Mass., the writer had an opportunity to inspect the plant while being operated by the original owner, Mr. Gilbert, and remembers reaching his hand down into the stream flowing through an abandoned cranberry bog which supplied the hatchery ponds, and withdrawing some vegetation which was literally alive with shrimp and which were giving the flesh of Mr. Gilbert's trout an extra tint.

Dr. Kendall had specimens of shrimp and samples of water collected from a stream at No. Windham, Maine. These proved to be G. fasicatus, and H. knickerbockeri. The waters of this stream are comparatively soft.

Specimens of shrimp were obtained from the preserve of the South Side Sportsmen's Club at Oakdale, Long Island, N. Y., the waters of which had been stocked with G. limnaeus. These specimens were furnished through the courtesy of Mr. Laird. The shrimp from this source proved to be G. fasciatus, and the analysis of the water as shown in the table closely resembles that of the waters in Connecticut where G. fasciatus thrives. Evidently the planting of G. limnaeus in these waters proved a failure.

The State Fish Hatchery at Hackettstown, N. J., presided over by our esteemed member, Mr. Hayford, is supplied with water from limestone formation similar to that at Caledonia, N. Y., and shrimp from this source have been identified as G. limnaeus.

Embody in his paper refers to shrimp at Auburn, N. Y., which he had already identified as G. limnaeus. In a recent letter he adds that in this water the shrimp are found exceedingly abundant in watercress and chara, and the hardness of the water corresponds closely to that of the stream at Caledonia, N. Y. Embody states that the water comes directly from limestone ledges and shows the highest degree of food richness that he has ever found.

In a recent trip to Canada I ran across a stream on a private preserve, in the township of Acton, Province of Ontario, the bottom of which was covered with chara. One handful of this chara, picked from the bottom of the stream and exposed, was discovered to be alive with large shrimp, afterwards identified as G. limnaeus. This stream was fed by springs from a clay formation and is evidently of the same type of hardness as that from the limestone formation at Caledoina.

A notable instance of the successful introduction of G. limnaeus is that of a fishing club at Castalia, Ohio, which owns a spring flowing from a limestone formation and of sufficient volume to produce a good trout stream. In this case the original stream, one mile in length, flowed in a practically straight line from the source to its discharge into a river. The grade of the country was so even and gradual that the stream has been artificially meandered until the one mile was extended to six miles between the spring and its discharge. This stream has profuse vegetation and the Caledonia shrimp constitutes

one of the important foods for its entire length. Here again, conditions are somewhat similar to those which exist at Caledonia, N. Y., in relation to water temperatures, degree of hardness and vegetation.

The following table gives the chemical analysis of certain brook and hatchery waters:—

**CHEMICAL ANALYSES OF BROOK AND HATCHERY WATERS**

**(Parts per 1,000,000)**

| | Hardness as Alkaline Carbonate | | Calcium | Magnesium | Species of Shrimp |
|---|---|---|---|---|---|
| Caledonia, N. Y. | Brook | 204 | 159 | 21.7 | G. limnaeus |
| | Spring | 199 | 141 | 20.9 | |
| Price Spring Brook. Auburn, N. Y. | Brook | 244.5 | 185.0 | 25.9 | G. limnaeus |
| Oakdale, L. I. | Brook | 22.5 | 2.5 | 2.5 | G. fasciatus |
| | Artesian Water | 17.0 | 1.1 | 2.5 | |
| Basin Brook, | Brook | 16.5 | 2.5 | 1.3 | G. fasciatus |
| No. Windham, Me. | Brook | 17.0 | 2.3 | 1.3 | |
| Joshua Pond, | Brook | 15.5 | 3.0 | 1.2 | G. fasciatus |
| E. Haddam, Conn. | Pond | 16.5 | 2.6 | 1.0 | |
| Whigville Brook, Burlington, Conn. | Brook | 16.0 | 1.3 | 0.8 | G. fasciatus |
| Burlington Hatchery, Conn | Brook | 12.0 | 0.4 | 0.4 | G. limnaeus introduced, but disappeared. |

It will be noted that there is only a slight difference between the hardness of the waters from Oakdale, L. I., and North Windham, Maine, Joshua town Pond and Whigville Brook, Connecticut, in all of which G. fasciatus is found in abundance. The hardness as shown in the table from the two waters in Connecticut may be regarded as the maximum hardness of waters throughout the state. In a very few instances, however, waters no harder than Burlington Hatchery Brook was shown to be, by the soap test, contained G. fasciatus but not in abundance.

In connection with this investigation, in every case where G. limnaeus has been found, the waters have proved to be from limestone formation and of cold spring water temperature. In making this statement it is only fair to Mr. H. K. Annin of James Annin & Sons to quote from a letter written by him on this subject:—

> "The results which you obtained from the addressing of shrimp customers which we submitted were about as might be expected. It has been our experience, due probably to lack of knowledge on the part of the observers, that very little satisfactory information can be obtained from them regarding the results of shrimp plantings. I am inclined to agree with you that Caledonia shrimp will thrive best in cold waters heavily impregnated with lime, although as previously stated, there have come to our attention instances where they have been very prolific in water apparently soft."
>
> * * * * * *
>
> "Several years ago we operated a hatchery plant in the western part of this state. The water supplying this was quite soft. We introduced, in such water, shrimp taken from Caledonia with wonderful results. This incident brought quite forcibly to our attention that Caledonia shrimp do not always require hard water in which to thrive."

It is unfortunate that it has been impracticable to obtain from the plant referred to above specimens of shrimp for identification purposes, and samples of water for analysis.

In order to determine how extensively shrimp are distributed in the waters of Connecticut and the kind of habitat in which found, the county wardens were assembled at the Joshua Ponds in the town of Lyme, where shrimp are fairly

abundant. They were instructed how to distinguish and collect the shrimp. At the same time a kit of specimen bottles was equipped. Standard soap testing outfits were also supplied and the wardens were instructed how to make soap tests in order to determine the relative hardness of each water examined. Collections were made from the trout streams in each county.

Tabulated reports were made by the wardens showing the name of the brook, the record of air and water temperature, the time of day, the water hardness as shown by the soap test, and other relevant remarks with regard to pollution, abundance of the shrimp, etc. When shrimp were found, specimens accompanied the report.

Of 444 streams examined 174 contained one, and in some cases, two species of shrimp, varying in abundance or scarcity; the water temperature varied from 53° to 80°.

In some counties only the smaller species of shrimp, H. knickerbockeri were found. West of the Thames River no shrimp were found.

The soap tests indicated that all of the waters are soft. Of the 174 specimens identified 43 were G. fasciatus and 131 were H. knickerbockeri.

The results as to H. knickerbockeri bear out the statement made by Embody that this species may be found in the cold water of trout brooks as well as in waters of very high temperature.

The species is so small that it is now dismissed from this discussion as not of sufficient size and abundance to be considered for general distribution in trout streams for the purpose of improving food conditions. In all probability it will be found along with the Eucrangonyx gracilis quite generally distributed where conditions are favorable, constituting one of the minute foods which go to make up the diet of small fish.

No specimen of the Eucrangonyx gracilis, *recorded as having been found at New Haven were collected.

The waters in which Gammarus fasciatus was collected varied in temperature from 50° to 75°. Embody reports finding G. fasciatus in waters of about 86°. Its abundance in Connecticut waters varied. Apparently those with a slight hardness, requiring six or seven drops of the standard soap tests, produced the most in numbers and also in size.

It is recognized that in the hands of eight inexperienced workers there may have been some slight variations in the comparative results.

*The Arthrostaca of Connecticut, by B. W. Kunkel, published under the auspices of the Connecticut State Geographical and Historical Survey in 1918, Bulletin '26.

In no instance did the far-reaching search in the waters of Connecticut discover the Caledonia shrimp and it is believed that there are no waters in the state which contain the elements essential to successful stocking with this species.

G. fasciatus has been found in many streams and in varying temperatures. It has been shown that many waters outside of Connecticut are inhabited by G. fasciatus in sufficient numbers to be an important factor in the food supply. There is an opportunity for more research on this subject.

It is intended to try to extend the range of G. fasciatus in Connecticut by transferring this species from waters where they are now indigenous to waters in which they do not exist. If failure follows these efforts, further studies of nature of the waters will follow.

It is evident that the introduction of G. fasciatus stands a much better chance of producing favorable results than the introduction of G. limnaeus, so long as many customers fail to take the precaution to secure knowledge of water conditions.

The natural conclusion is that the introduction of the Caledonia shrimp, G. limnaeus, does not yield favorable results in the ordinary trout stream; that it is useless to distribute this species for the purpose of increasing the food supply in any trout water unless it is of the temperature of spring water and of the extreme hardness which results when the source is in a limestone formation. The minimum hardness of water in which G. limnaeus may thrive has not been demonstrated and it is not known.

In connection with the investigation of Connecticut waters acknowledgment is made to the State Water Commission for its hearty co-operation; to R. B. Friend, Assistant Entomologist of Agricultural Experiment Station at New Haven, for the identification of numerous specimens and to Dr. E. M. Bailey of the Experiment Station for the various water analyses.

It is generally conceded that North America leads in fish culture as to quantity, operation and number of species concerned. In the manner of administering individual waters for quantity production under natural conditions, it is probable that Great Britain leads with two or three countries on the European continent as close seconds. Much thought and study is given to this subject by the landowners who, together with angling clubs and organizations, control the fishing privilege. The reader of the "Salmon and Trout Magazine," the journal

of the Salmon and Trout Association, London, cannot fail to be impressed by the high quality of the reading matter contributed from such sources, and the evidence of the intelligent thought devoted to "farming" the streams. Not only shrimp but snails and aquatic insects are used to supplement the fish food for trout streams where natural conditions both for fish and fish food have been augmented by increasing to the maximum the number of pools through the improvement of the barren shallow reaches.

It is inferred that the successful introduction of shrimp in British waters is limited to what in this article have been termed hard waters.

In the English writings on this subject the frequent reference to chalk streams is explained by W. Carter Platts, Editor of the special angling page in the Yorkshire Post. After explaining that their streams are not subjected to the extremes in temperature which are experienced here, he says:—

> "Chalk stream" was originally the term applied to an English river springing from the chalk formation, often in considerable bulk, and not subject to violent floods, slow in current and usually devoted to dry-fly fishing. But now the term is more generally applied to slow lowland rivers of somewhat similar characteristics whether they spring from the chalk or not. It is mostly a South of England term, and is useful as differentiating these dry-fly rivers from the rapid, rollicking streams which, for the want of a better term, are classed as "Moorland rivers," and are fished mostly with the wet fly.
>
> We have no official government surveys with regard to fish culture here. Indeed, that branch of economics is left almost entirely to private enterprise and the activities of the various clubs and associations. Still a good deal of biological research has been going on and certain results seem to have been definitely reached. The snail bearing possibilities of a water—and indeed the production of fish food largely—has been found to depend on the acidity or otherwise of the water. Many of our moorland streams, having their origin among the peat bogs, are acid in their early stages, and it is in these lengths that snails will not thrive. Also in some cases the violent floods sweep them away by physical force. It

has been shown that if the water of a stream reacts to the acid test it will not produce the green filamentous algae on which the snails live and which is also responsible for a world of diatoms and other minute morsels bound up in the genesis of food production. But where the water is neutral, or with just an alkaline tinge, the algae and consequent fish food are readily produced, and the streams from the chalk and limestone possess these characteristics.

If you work by the soap test, I suppose that you will generally find that the hard waters are non-acid and produce fish food, including snails, and that the soft waters are more or less acid and not favorable. But I think a direct test for acidity is the safest course.

The "Freshwater shrimp" known in England is Gammarus pulex, and that is the variety referred to in my "Trout Streams." I believe that in quieter waters G. fluviatilis is sometimes found in numbers, but pulex is the fish culturist's stand-by.

Kendall in his bulletin gives some very interesting data about the use of shrimp (*Gammarus pulex*) at fish cultural establishments of Europe where arrangements are made for actually raising these Amphipods in small ponds from which they are conducted to the ponds in which the trout are being reared. Apparently the waters of the European hatcheries to which he refers have the proper qualities for producing shrimp in very large numbers or it would be impracticable to provide an adequate number of shrimp for intensive fish rearing. It is well worth while for any one who has waters favorable to rapid production of shrimp to read Kendall's article on their use in Europe. The subject is rather foreign to the object of this particular article, but when it comes to the matter of introducing shrimp to the trout streams of the country it is well worth while to first investigate the waters and learn in advance whether it is worth while to introduce G. limnaeus or G. fasciatus.

### *Discussion*

DR. CHAS. K. STILLMAN: From personal observation I can say that shrimp are fairly common inhabitants of the streams in the southeastern portion of the state, particularly the sluggish ones having more or less aquatic vegetation. They also occur in shaded rapid woodland streams having such plants as crowfoot, water celery (tape grass) and fontinalis,

particularly where there is marginal debris of soft mud rich in half rotted wood fibre or plant debris. In the rocky open streams I do not recollect observing them. In other words, may fly streams rather than stone fly streams are more congenial to them.

The small varieties are more common than the large, but occasionally both small and large occur in the same stream.

There seems to be some difference in the value of the shrimp as food for trout in the various streams. In Snake Meadow Brook, for example, I did not find evidence that they formed as large a part of the diet of the fish as their numbers would seem to suggest. In many streams the trout feed heavily upon them and are exceptionally red in color of flesh, and rich in flavor. The flesh also will be yellow on this kind of diet instead of deep red.

Some of our best shrimp streams are "soft water" streams with temperatures up to 75 degrees but there are favorable conditions as to vegetation and debris. My impression is that the fresh water shrimp will do best in pure sweet waters where there is considerable tender aquatic vegetation.

Streams poisoned by the leaves and bark of slash, following deforestation, so that trout do not survive, have the effect also of killing the shrimp which formerly abounded in them.

MR. DINSMORE: In a spring below the hatchery at Springfield, South Dakota, there is a shrimp which is very abundant. It is a small stream in which thousands and thousands of these shrimp are found; and I have never seen trout grow as rapidly as they do in that spring.

PRESIDENT TITCOMB: Is that a limestone water?

MR. DINSMORE: I think so.

DR BELDING: Do you get the fairy shrimp here—Branchipus?

PRESIDENT TITCOMB: No, and it is not mentioned in the Asthrostaca of Connecticut.

DR. BELDING: It is common in eastern Massachusetts.

MR. GRAHAM: Your talk brings me back to a visit you once made to Berkeley, and you remarked about the color of the trout. We got a dip net and scraped out the side of the pond, and we found what you said was Caledonia shrimp, in great numbers. Do you remember that?

PRESIDENT TITCOMB: Yes.

MR. GRAHAM: That water has a hardness of 2-4/10 per million.

PRESIDENT TITCOMB: That shrimp is probably G. fasciatus.

MR. GRAHAM: I have often wondered why we did not have shrimp in the other streams we are interested in, and I should not be surprised if that is the answer.

DR. EMBODY: In our survey work during the last two years we have found a number of streams that have contained Caledonia shrimp, but all these streams had luxurious growths of water cress, and the waters were

all hard. The hardness of the spring at Auburn is over 200, and I have never seen Caledonia shrimp as abundant anywhere, outside Caledonia, as they are in that spring, not only in the water cress, but in the submerged algae that occur there. The little Hyalella is very widely distributed all over the United States; you find it from New England to the Pacific coast; you find it in all kinds of water. The Eucrangonyx we find sometimes in stagnant waters. The Eucrangonyx grows much larger in Indiana than it does here in the east. Gammarus limnaeus is limited to water heavily impregnated with lime, and when you find a large shrimp which occurs in waters not impregnated with lime it must be either Eucrangonyx or Gammarus fasciatus.

President Titcomb: The water cress is not really a factor, except that they require vegetation?

Dr. Embody: In a stream down near Syracuse, the bottom of which is covered with poriferous limestone, some calcareous deposit, there are little holes in the rock, and in those little holes you will find Gammarus limnaeus. There is no vegetation, not a bit of water cress in the stream, but this porous rock affords an excellent hiding place for the shrimp, and I believe on account of that they have been able to hold their own against the trout there.

Mr. Laird: Did I understand you to say that the shrimp I sent you were not the Caledonia?

President Titcomb: Yours is not the Caledonia, it is a smaller size, Gammarus fasciatus.

Mr. Laird: What happened to the Caledonia shrimp?

President Titcomb: Well, that is what I want to find out. I would like to pursue the inquiry to the point where a man may know before he buys shrimp whether he is going to get results.

Mr. Laird: I did not know the difference between the two shrimp, and I suspected that we were not getting any results from the shrimp we were buying.

Mr. Hayford: Curiously enough, we hunted all over the northern part of the state in an effort to find some of these shrimp, and could not locate any; whereupon my four year old boy goes out and finds them in the brook in front of the house. There is a lot of water cress in the brook, and we can put a net in just below the water cress and get lots of them. There are large numbers of the shrimp at the upper end of a pond, and the boys gather thousands of them.

President Titcomb: For the information of anyone who is interested in collecting shrimp or transferring them from one water to another, the common method of collecting them is to rake out the vegetation, whatever it may be, and drop it on to a piece of wire netting—a hatching tray is all right—then set the wire netting over a receptacle, and the shrimp will drop through. It is desirable to have water and moss in the receptacle. You can collect them very easily.

# HATCHING EGGS WITHOUT RUNNING WATER

By Prof. N. Borodin.

1. Hatching eggs in humid atmosphere after system of Dr. O. Grimm, Russia.

It is well known to every fish-culturist that fertilized eggs can be kept, during transport, without running water, just in humid air, maintained by dripping water of melted ice which is placed on the top of a pile of trays, filled with eggs. The eggs are usually covered by a layer of wet cotton. The same method has been applied by the late Dr. O. Grimm, eminent Russian fishculturist, in the construction of an apparatus for hatching eggs without running water. It was a wooden drawer with movable hatching trays, similar to those used in Williamson hatching troughs.

Eggs of salmon or trout after fertilization are placed on the trays in the usual way and eggs are covered with a layer of cotton. All that remains to do afterwards, is to sprinkle the cotton which covers the eggs twice a day with water from a watering can with fine holes.

The experiments of hatching eggs by using this new method were made first at the Nikolsk State hatchery, Novgorod gov., Russia, and proved to be satisfactory. Then it was used successively on a large scale, in hatching salmon eggs at Luga State hatchery. This hatchery was equipped previously with several hundreds of Coste's hatching troughs which require a good current of water. Water was pumped very high and with difficulty from the river. Thus, Dr Grimm decided to apply his new system of hatching eggs without running water just using the same Coste's troughs. He had in view that, as the time of fry emerging should come, it would be very easy to let run a current of water into the troughs as it was usually done before. This method was applied at the said place during two years and has shown very good results.

The great advantages of this system lie in the fact that the consumption of water is a minimal one—for spraying cotton during the larger part of the development of the eggs and that egg loss is much less than in the case of hatching eggs in the ordinary way by using running water. In fact this loss is so insignificant that the picking of dead eggs becomes alomst unnecessary.

Salmon eggs at the said Luga hatchery, near Petrograd, were kept under said regime during about three months—November, December and a part of January. Then the current of water was let in and the cotton cover was taken away.

The same method was tried for hatching sturgeon eggs and has shown the smallest percentage of eggs lost. In this case eggs were kept only one week, because after this time the sturgeon fry was ready to emerge. The method was applied especially in order to avoid a large amount of egg loss, caused by fungus, and it gave very good results, namely, only 0.9% of lost eggs as compared with 5% in all other hatching apparatuses.

2. Hatching eggs in artificially aerated water. This method of aerating water instead of changing it by a current, used in aquaria, was applied in 1915 on the Ural river, Russia, in hatching sturgeon eggs and in rearing sturgeon fry. The aerating of water (filtered, boiled and cooled previously) was effected by a system of thin lead pipes, ended by a porous nozzle, introduced into Chase jars and hatching troughs. The air was injected by means of rubber ball provided with two holes, compressed and loosened periodically by a small hot air motor, working from the heat of an ordinary oil lamp. The air enters from one hole and is blown into the other, connected with the pipe system. Porous nozzles at the end of the lead pipes were usually placed near the bottom of the Chase jars so that the air bubbles agitate the eggs as usually takes place in the Chase jars with current water. Sturgeon eggs were hatched by this system with very small loss—3 and 4 per cent, while with the current water the loss reached from 7.3 to 12.3 per cent.

Sturgeon fry was kept also perfectly well in an aquarium and hatching troughs with aerated (not changed) water during one month of the rearing period when it was fed by living crustaceans and chopped worms.

## INFORMATION ABOUT THE ARTIFICIAL PROPAGATION OF STURGEON IN RUSSIA IN 1924, 1925 AND 1926.

1924. About 8 mlions of sturgeon eggs collected and 7 millions of sturgeon fry planted into Arax River (Kura's Riv. tributary, Caucasus).

1925. 6.1 millions of sturgeon eggs collected and 5 millions of sturgeon fry planted into the same river.

1926. 13.2 millions sturgeon eggs were collected (8.4 mill. star sturgeon, Acipenser stellatus and 4.8 mill. Russian sturgeon, Acipenser Gueldenstaedtii). Twelve millions sturgeon fry of both species planted into the same river.

*Discussion*

MR. DINSMORE: On one occasion in northern Maine I had about 50,000 eggs to incubate. I wanted to get them out before the frost came, and there were not enough eggs to make it worth while incubating them in running water. So we packed them in our ordinary shipping cases with moss and netting, regulating the temperature to 50 degrees, and in this way we incubated the eggs to the eyed stage just as well as if they had been incubated in running water.

MR. LAIRD: At Northville, Michigan, I made an experiment some years ago in which I held lake trout fry in the sac stage eighty-five hours, showing that it might be possible that the fry could be transferred for trips of three or four days' duration if necessary. I held them in the sac stage in common egg-shipping cases, keeping the moss dampened from time to time.

MR. RADCLIFFE: That brings to mind the system that is in vogue in Europe. I think it is Germany that gets large quantities of very small eels from England. These young eels are packed in cheese cloth trays with some sort of screen at the top and a cake of ice so placed that the water from the melting ice will fall over them. It seems to me that the system could be used with advantage in the transporting of many of our fishes. Certainly some of the hardier types could be transported out of water, with a proper surrounding medium, better perhaps than they could be in the water.

MR. WALCOTT: I would like to ask Dr. Borodin whether it would be possible to cultivate the sturgeon in the Connecticut river, assuming that we could get eggs. Is it a practical thing, or a purely theoretical thing? Must they have a more northern climate? They have been known to be in the Connecticut River; in former days, fifty or sixty years ago, many of them probably came in to the Connecticut River for the purpose of spawning.

PROFESSOR BORODIN: I should say that so far as I know the waters of the Connecticut River would be all right for sturgeon; in fact, there are sturgeon there. The difficulty would be to get the fry or the eggs; that is the trouble.

MR. RADCLIFFE: Mr. President and Members of the American Fisheries Society, the man engaged in the study of problems of oyster culture frequently does not think of his problem in its larger relation to the field of aqui-culture. I think the same may be said often times of the fish culturist; he thinks of his work as a little branch all by itself, and so on through the various gamuts. I have therefore attempted here, in a very cursory fashion, to give the briefest possible review of the status of aqui-culture.

# PROPAGATION WORK AND PROBLEMS IN PERPETUATING THE SALMON FISHERIES OF WASHINGTON

By L. E. Mayhall,

*General Superintendent of Hatcheries, State of Washington.*

## INTRODUCTION

Because of the State of Washington is one of the younger states of the Union and the center of the world's greatest salmon industry, the problems of propagating, protecting and perpetuating the industry have been of no small magnitude. Along the line of propagation work, progress has been very satisfactory. In thirty years the department has developed from three salmon hatcheries of less than four million capacity each, and no rearing capacity to sixteen hatcheries, with capacities varying from five to thirty million each and with rearing capacities developed at one-half, the hatcheries ranging from two to nine million each, with an average egg take for the past four years of 165,451,000 per year.

The economic side of the problem has been very well taken care of. In 1912 it cost 88 8/10 cents per thousand to operate the state's salmon hatcheries, in 1913, 56 cents and in 1914 43 cents. The past four years it has cost an average of 42¾ cents per thousand eggs. This is very satisfactory when it is considered that common labor has advanced from $60.00 per month in 1914 to $110.00 in 1926. Superintendent's salaries from $70.00 in 1914 to $135.00 in 1926, and the cost of supplies has advanced in like proportion.

The above economies have been made possible by the introduction of permanent concrete construction in the building of hatcheries, which stops the upkeep cost of temporary wood construction; the development of permanent rack construction in the rivers that withstand the high waters caused by our heavy rainfalls; the replacement of surface wood constructed flume systems with creosoted underground water mains; the utilization of our wonderful highway system by using trucks for transferring supplies and materials; and the transfer of eggs from the spawning ground to the hatcheries as well as the young fish to the planting areas of the rivers where they may have advantage of the best feeding opportunities.

The department is maintained on a strictly operating basis. The hatcheries are open to inspection and visitors at all times, the same as any factory or industrial plant, but there are no uniformed attendants, no extensive landscaping effects, no re-

ception rooms or ornamental fish, just plain salmon hatchery operations. The department is maintained by a direct tax on the commercial industry and now has a reserve cash balance of more than $200,000.00.

## VALUE OF ARTIFICIAL PROPAGATION PROVEN

Thirty years of operation have proved the merits of artificial propagation. The Kalama Hatchery on the Kalama River, a tributary of the Columbia River, from 1896 to 1900 took an average of 3,500,000 Columbia River chinook eggs per year. This egg take has gradually increased. The average egg take for the past five years, 1922 to 1926, has been 25,560,000 per year.

The Chehalis Hatchery, on the Satsop River, a tributary of the Chehalis River flowing into Grays Harbor, for the four years, 1911 to 1914 inclusive, took an average of 3,235,000 silver salmon eggs per year. From 1923 to 1926 the average take was 22,350,875 eggs per year.

The Samish Hatchery, on the Samish River which flows into Puget Sound south of Bellingham, for the four years, 1899 to 1902 inclusive, took an average of 1,857,000 silver salmon eggs per year. The egg take for the four years 1923 to 1926 was 10,395,000 per year.

At the Skykomish Hatchery, located on a tributary of the Snohomish River flowing into Puget Sound at Everett, the silver salmon average egg take for the four years, 1913 to 1916 inclusive, was 5,550,000 per year; for the four years, 1923 to 1926 inclusive, it averaged 15,490,000 per year.

The Green River Hatchery, near Auburn, Washington, located on a tributary of the Duwamish River flowing into Puget Sound at Seattle, in the years 1905 to 1908 inclusive, took an average of 9,004,000 per year, all species combined. For the four years 1923 to 1926 the average egg take of all species was 25,103,000 eggs per year.

When the above facts are taken into consideration and studied carefully it will be seen that opposition to and criticism of the department's practical methods in the artificial propagation of salmon are entirely out of order and not based on facts, even though the greater amount of such criticism has come from supposedly scientific authorites.

## THE REARING OF SALMON

After constructing numerous differently designed rearing ponds and using them for several years, the department has

adopted a circulating pond, 20 ft. wide by 80 ft. to 90 ft. long with round ends and a center wall that directs the current causing a perfect circulation of the water with a separate water supply and discharge for each pond.

The merits of this style of rearing pond are well expressed in a letter received from Hugh C. Mitchell, formerly Field Representative for the Columbia River Salmon Protective Association, and now, Oregon Director of Hatcheries, which states, "I visited your Kalama Hatchery last Friday and there saw as fine a lot of young salmon as it has been my good fortune to examine in the Columbia River Basin this season. The fish were in splendid condition. From now on I can see nothing but the circulating pond system, economically constructed and operated, splendid circulation and holding capacity. Your work in perfecting this pond system means everything to the industry." Each of these ponds has a maximum rearing capacity of 600,000 salmon fry and the department has thirty-one in operation and four under construction.

The propagation and rearing of the young salmon is but one part of the department's problems of perpetuating the state's great salmon industry. The rapid commercial development of the state's natural resources is bringing up problem after problem in rapid succession.

## FISHWAYS

The fish ladder problem is fairly well in hand, although in some cases the difficulties seem to be unsurmountable, as in the case of one power dam which is more than 200 ft. high. The storage back of it is large and the generating installation is greater than the water flow and is operated in a hook-up with other power plants. During periods of the day when demand for power is low this plant is shut down and the water is conserved which leaves the river dry for miles below the power house. As the entire water flow is conserved, there is no overflow to enable the young migrating fish to pass down over the dam. Besides the above mechanical difficulties the owners of the power development secured a court decision to the effect that the power is of more importance to society than the salmon. Thus we see a very important salmon stream going down before the advance of commercial development.

The department has never taken the position that the state's development should be stopped or in any way obstructed, but is asking for cooperation in solving these problems that all may live and prosper.

The Puget Sound Power and Light Company, owners of the Baker River Dam, are setting the world an example in cooperation, which resulted in a 75% success in putting the first season's run of salmon over this 200 foot dam. With extensive improvements just completed and the knowledge acquired from the past years' experience, there is no doubt that much greater success will be attained this coming season. This fishway as operated last season consisted of pools 6 ft. x 10 ft. with a rise of two feet from pool to pool, to an elevation of forty-two feet. Then there was 700 feet of flume that reached to the upper pool at which point there was a submerged tank car so arranged that the salmon entered it voluntarily. At intervals, as often as necessary, the car was hauled up an inclined track by an electric hoist to the crest of the dam, where they were dumped into a receiving tank and passed through a flume to the quiet water above the dam. The 700 feet of flume and incline hoist are being dispensed with this season. A standing cable is being used which reaches from a tower on the crest of the dam to the upper end of the fishway which is about 700 feet distant. A travelling tank is swung on this standing cable which is operated by an electric hoist. The fish enter the tank as before mentioned at the head of the ladder and are disposed of on the crest of the dam as before. The destructive action of the freshet water passing over the dam, the rock slides down the walls of the canyon and the ice forming from the spray of the dam made successful operation and maintenance of the flume and incline hoist impossible in this 700 feet of canyon.

There are two very important items in the successful designing of a salmon fishway: First an adjustable gate at the foot of the fishway causing a waterfall of about one foot to attract the fish into it, and second, an arrangement that will not obstruct the salmon from entering the fishway or passing up from one pool to the other, but will prevent them from retreating down the fishway or out of it once they have entered. The introduction of these two items developed by men in the State Department of Fisheries of Washington are the only advancements made in the designing of fishways in this state in the past thirty years.

For many years various and sundry devices have been brought forward, many of them patented, for the purpose of elevating or passing fish over high dams where fish-ladders of the commonly accepted design would be impractical.

Quite recently considerable money was advanced by this department to aid experiments with hoists, and a good deal of

newspaper publicity resulted, but no new knowledge was gained, except an admission that it was first necessary to get the fish corralled to operate any hoisting device.

The different patents and devices for elevating migratory fishes over high obstructions do not enter into the problem of getting the fish into the device. Getting possession of the fish, and starting them on their ascent of the obstruction, is and always has been the greatest problem.

Our departmental work has always been based entirely on this phase of the problem, and it has not been deemed of any value to waste time, money and effort on mechanical hoisting devices, for the engineering profession has already developed and can provide many practical methods to use and adopt as conditions may warrant.

## DOWNSTREAM MIGRATION.

The prevention of young fish migrating down stream from entering the irrigation canals and power wheel pen stocks is a problem that the department is seriously interested in at the present time.

There is in the Yakima Valley the Sunnyside canal about eighty miles long, fifty feet wide and ten feet deep, with a current velocity of six feet per second. The Wapato canal of about the same dimensions and about sixty other irrigating systems of lesser size all taking their water supply from the Yakima water shed which is a part of the spawning area of the Columbia River spring chinook salmon and steelheads. On one lateral ditch three feet wide, seventy miles from the head of the Sunnyside canal, six young chinook salmon five inches long have been counted per minute passing on to the alfalfa fields. This waste has gone on until it has become a disaster to all fishing interests of the state.

The mechanical problem of screening these and other canals of the state is of such magnitude that it seems to be beyond the financial ability, engineering capacity and authority of the Fisheries Department. The trouble no doubt lies in the fact that our statesmen, representatives in Congress and engineers in promoting and putting through these great developments never realized, appreciated, or knew they were destroying one of the state's greatest industries, the fishing industry. If they had ever realized the damage that was sure to follow, without a doubt funds would have been provided and the canals so designed with screens that the seaward migration would have been efficiently taken care of. It is poor business to delay the

repairing of a ship until it sinks to the bottom of the ocean. So will it be poor policy to delay screening our irrigation canals until the fishing industry has gone down.

## POLLUTION

The rapid development of the pulp and paper industry is bringing up the question of stream pollution in the State of Washington. Steps are being taken to handle this matter before any extensive damage may be done to our streams, which up to the present have no appreciable polluted conditiions.

With persistent and efficient propagation, continued improvement and development of the fishway, the mastering of the canal intake screen, the proper safeguarding of the state's waters from pollution, the further restriction of fishing appliances, the maintenance and extension of our present fish preserves, combined with the present efficient law enforcement, it would seem that there is no reason why the salmon industry cannot be stabilized and perpetuated.

# THE STATUS OF AQUICULTURE

By Lewis Radcliffe.

*Deputy Commissioner, U. S. Bureau of Fisheries*

In Europe, aquiculture is much farther advanced than in this country and the methods are supported by very extensive scientific investigations. In the Orient, great dependence is placed upon aquiculture and the production of food fishes is large. Excepting Japan, the methods are largely empirical, the results of trial and error over a period of centuries, of handing down the methods from father to son. We know that the resluts are good, but we do not know the underlying principles, or how to improve on them. In this country so long as we have had an abundance of fish and meat, at low cost, the incentive to engage in fish farming has been lacking. The average price of our annual fishery harvest of over 3 billion pounds is less than 3½ cents per pound to the fisherman. The average price of all fish landed by American fishing vessels at the ports of Boston and Gloucester, Mass., and Portland, Me., totalling about 200,000,000 pounds per annum, during the past decade has ranged between 3 and 5 cents per pound, and this includes low priced haddock and high priced swordfish and mackerel. Obviously under such conditions, the only hope of the fish farmer was to deal in some specialty such as trout. But that day is drawing to a close. Improved methods of merchandising is boosting the price of fish. We are beginning to realize that the supply of fish in the sea is not inexhaustible. Our fresh water areas and our runs of anadromous fishes are being rapidly depleted.

As a result of these changes in conditions, interest is growing in the possibilities of water farming. The problems of pollution, super-power development, deforestation, and reclamation have forced themselves upon the attention of the scientist and we may expect his aid in their solution.

With about 22,000,000 automobiles or one for one person in five in this country, with over 500,000 miles of surfaced roads and with shorter working hours, many more of our people are seeking recreation in angling. This has resulted in an increased drain on the fish supply, throughout the length and breadth of our land. This growing army of recreationists is also forcing its attention on you, who are engaged in keeping our streams stocked, compelling closer scrutiny of your methods and greater exertion to plant more and better fish in the streams.

Conditions are fast changing. The hydrobiologist is finding a market for his services and institutions of learning are beginning to take notice of the need for training such men. Such an organization as the National Research Council has interested itself in the subject and now has a well-organized Committee on Aquiculture which is studying ways and means of furthering the development of this science. However, the greatest advance is being made in institutions of learning, such as the work under Needham and Embody at Cornell, Cobb at Seattle, Davis at the Bureau of Fisheries and Dr. Emmeline Moore in New York. And what is far more heartening is the avidity with which men like Titcomb, Buller, Hayford, Leach, and others are making practical application of the results of these investigations. Because of these conditions, I believe that advances made in fish culture in the decade ending two years hence will far exceed that of several previous decades.

As you know, the bureau's work under Dr. Davis may be roughly divided into three phases: Cultivation of the cold-water species, such as the trouts; and warm-water species, such as the basses and sunfishes; and, third, studies of fish diseases. The Holden, (Vt.) station is now devoted to experiments with trout, without regard to the size of its output. There, comparisons are being made with different foods—beef heart, beef liver, sheep heart, (cooked and raw) soy bean meal, shrimp and fresh-water mussel meal. The effects of sunlight on the growing fish are receiving attention, and selective breeding experiments have been begun to produce a stock which is disease-resistant, matures early, grows rapidly, and produces a greater number of eggs.

At the Fairport Biological Station last year 21 ponds were devoted to the propagation of large-mouth bass and blue-gill sunfish, on an investigative basis. Experiments included treatment of ponds to produce a maximum food supply, studies of types of rooted vegetation; wintering of ponds wet or dry; effects of cultivation of bottom of ponds and liming on the vegetation; uses of fertilizers, of forage fishes, etc. Consideration is also being given to the number of brood fish required per unit of area, desirability of rearing two or more species in the same pond, and other facts essential to the development of water-farming along sound scientific lines.

In addition, a great deal of attention is being given to fish diseases—the causative organisms, means of controlling or eradicating the disease—and such other things as the fish doctor finds necessary to save the stock at your stations. This is

but a glimpse of the manifold activities being carried on in this field under Commissioner O'Malley. I believe it gives sufficient grounds for the belief that in the near future aquiculture will be placed on a much firmer basis in this country. There will be less guesswork, and more fact, governing what we do. We shall be able to apply the yard-stick to each water-area to determine wherein it is deficient, and we shall know how to eliminate or make up in part such deficiencies as to produce a maximum output. The exchange of experiences and ideas made possible by the annual meetings of this society contribute much to the advancement of the science of aquiculture.

### *Discussion*

**Supplementing his paper, Mr. Radcliffe said:**

The National Research Council at Washington is interesting itself in this larger problem of aquiculture and is now studying ways and means of getting information as to the methods in Europe and in the Orient, and I am certain that any information that can be got in that way will be very helpful to the fish culturists.

I would like to call your attention to what is happening in some of the other industries. We have been astounded at the achievements of Lindbergh, Byrd, Maitland and Chamberlin, yet we must realize that those achievements would not have been possible had it not been for the scientific man doing his part and solving the difficulties that made these accomplishments possible. In the field of radio, that industry in a period of five years has grown from an experiment to a leading industry; from a single experimental broadcasting station to over six hundred in daily operation; from a local audience of a few thousand people to a national and international audience of about ten or fifteen millions; from an industry employing a few thousand to an industry today employing over three hundred thousand; and from an annual business of $2,000,000 to one of over $600,000,000 at the present time. Now, what was it that made this growth possible? It was the work of the scientist in solving the various problems that were met with as they went along. So that in this field of water farming your dependence must be placed in a much larger degree upon the scientist. You must provide larger funds and larger appropriations for the carrying on of such work. And right in that connection I want to say that the average salary of the men at the fish cultural stations is miserly, to say the least, and that something has got to be done to raise the plane of the industry as a whole.

MR. HAYFORD: On my way back from Mobile last year I spent a very pleasant afternoon with Dr. Radcliffe. Probably I am in as good a position as anyone to make this statement: I do not believe, from the experience we have had, that we appreciate the scientist as much as we

should. When I stop and think of what we have been able to do down in New Jersey with the co-operation and advice of Dr. Davis, Dr. Embody and others who have worked with us, I realize that their contribution to the problems we have met has practically revolutionized the whole thing so far as we are concerned. Certainly it will be quite a few years before we can do any of the things we would like to do in connection with fish culture if we do not rely upon scientific help. Dr. Davis, for instance, has been at our plant, I think, five times in the past year, and every time he comes, a lot of new things of value are brought out; I could cite the instance of the golden shiner, and others. It is too bad he could not visit more hatcheries and spend a day or two with them.

MR. BULLER: I am very much interested in Dr. Radcliffe's paper, and particularly in that part of it which deals with the compensation of the men. As I look about I often wonder how it is that we can keep ourselves surrounded with the men we have, when you consider the compensation that they receive. It is about time that we reached the stage in the different states where the men at the hatcheries and the scientists who are giving us this valuable assistance should receive a greater incentive to remain in the work. I would urge upon every commissioner to take this matter up actively with the budget officer or the governor or whoever is in authority in the matter of the determination of salary, and also with the senators and congressmen, so that some action can be taken at Washington to provide that the men connected with the different bureaus may receive better compensation.

MR. JOHN N. COBB: Some time ago we collected statistics from the various states as to the compensation paid to the different men, and it made a very interesting table. One thing that struck me was this: how many common day laborers would work for the compensation we are paying to those who are supposedly trained men? You heard in the paper sent in by Mr. Mayhall that they paid the superintendents at one time $70 a month, and that now they have got up to $135. My recollection is that he is the man who is getting the $135, and the others get $110 a month. If you consider that a proper compensation for the superintendent of a hatchery who is supposed to know something of what he is doing, I don't; I think it is a beggarly compensation. You are never going to get anybody from the outside to come in and help you if you cannot pay him more than that.

I am in the business of training men along fish cultural and other lines, and naturally we are trying to sell these men to the industry; but we have had practically no desire to sell them to the State Fish Commissions unless the compensation is increased. These men are going out and they are going into the private hatcheries. The private hatcheries are waking up and are paying compensation that is far in excess of that of the state or even of the federal government; and as a result the best men are being taken away from the federal and state service. In other

words, they are gradually taking away from you people your best men and putting them into the private hatcheries. You will have to wake up and raise your salaries in order to prevent this, and until you do wake up you are going to have trouble in operating economically and safely.

I do not want to talk too much on this subject just now, although it is a matter in which I am very much interested, and it is my intention sometime to publish the little table that we made up. I thought the State of Washington was about as backward a state as any in the matter of compensation to its men, but I find that we stand quite high in that respect —surprisingly so when you consider that $110 a month for a hatchery superintendent includes his house rent. We found a few men scattered throughout the country who were drawing considerably more, but they were bright and shining lights; they were like light houses in the mist. The rest of them were down around $90 to $110. I think if you were to work it all out you would find that the average compensation for state hatchery superintendents throughout the country is in the neighborhood of $100 to $110. You know that you cannot go out and hire a man to dig a ditch for that money to-day, and it speaks well for the sense of loyalty of many of these men that they have continued to work year after year for this beggarly compensation when they could have quit fish culture and gone out and done better as carpenters or something else in the outside world. In other words, they have loved the industry and have stayed with it, even when the industry was sliping out from under them and leaving them virtually to carry the burden of the increased cost of living.

President Titcomb: Are there any further remarks on this tender subject? It seems to me that we are working in a sort of vicious circle. We pay poor salaries, and the result is we get poor men. Those fellows from the colleges, when they first come to a hatchery, are not worth a large sum of money. They have the making of a good man, but they have to show the stuff that is in them before they are entitled to a large salary. We have got to work together on this. When a man earns good wages he can usually get them if he has got the stuff in him. I am quite in accord with Mr. Cobb about the fact that a great many of our men have stayed in the work for the pure love of it rather than because they could not get a living out of it. Some of them you could not drive away from that kind of work, even if you cut their salaries in two; and the only man who makes a good fish culturist is the man who loves his work. I think that applies there more than it does in many other lines. We find it very, very difficult to get good men, and we are ready to pay a good man when we get him. You take a man off the farm, a good, steady worker—$4 a day looks awfully good to him at the start, but after a while he gets an automobile—which does not

make him worth any more—and he needs more money in order to run it. There are a good many sides to this problem. I wish we could have more of the educated type of man. I am not a believer in the civil service rule that in order to be a fish culturist a man has to pass the examination that the Bureau of Fisheries requires, because some of the best men in the country could not pass that examination today. But that is because the men had the stuff in them, regardless of the fact that they did not have the schooling. If the same man had the college education which Mr. Cobb, I suppose, could give him or if he could have had it from some other school, whether a fisheries school or not, he would acquire more quickly the knowledge which is necessary in practical work, and would go still higher.

# THE USE OF ZONITE IN TREATING GILLWORM

BY JAMES A. LAIRD.

At the meeting in Denver, Mr. Foster read a paper on "Fish Diseases in Missouri," and during the discussion following I mentioned Octobothrium, which I believed was the name of a gill worm that gave me a lot of trouble. After a sample of infected gill was sent to Dr. Davis, Pathologist, U. S. Bureau of Fisheries, the name Discotyle Sagittatum was given as more correct.

This small brownish gray worm about three-tenths of an inch in length attached itself to the gill filament of the larger brook trout only and a few of the rainbows; fish under six inches seemed immune. The gills would become very pale in color, the fish would lose their activity and appetite and soon die, apparently from loss of blood and inability of the gill to function.

I had tried salt solution dipping of various strengths without success, by dissolving large quantities of rock salt which was partially successful in that it would check the mortality for a few days but there would be a repetition of the losses. I used several strengths of vinegar for short and longer periods without success, because of the fact that the worm was so imbedded in the gill filament that the treatment would reach and kill only a portion of the parasites.

Dr. Davis kindly came to the South Side Sportsmen's Club and he tried Glacial acetic acid without success, because the worms were so buried and a long enough dip in a strong enough solution was fatal to the trout.

A few days after Dr. Davis' visit I struck upon a remedy in this way. The year previous I was at death's door from a blood poisoned arm and I remembered when convalescing that the doctor at the hospital kept my arm wet all the time with a bandage which was saturated with Zonite and changed very often. I thought if Zonite could kill the germ of blood poisoning which is so virulent, it ought to kill the other if applied properly. I then tried to figure how to apply it. First I used a dip without success for the same reason the Glacial acetic acid would not work, then I tried an atomizer and had the boys take the fish in their hands and by bending the lower jaw back the mouth would open and the gill filament would spread open so that the spray would hit every part of the membrane; then it was all off with the worm.

We used a one part Zonite and five parts water solution, as soon as this mixture hit the worms they would curl up and let

go. I used three hatchery troughs to do the work, one to hold the fish to be treated, one to hold the fish over when spraying and one to hold the fish after treatment, until they could be carried to a clean pond that had been prepared for them.

I soon found that the atomizer used for nasal treatment was built for less strenuous work, so I rigged a container, hung it on a nail and with a small rubber tube and a reduced outlet I could irrigate more quickly and affectively.

The beauty of Zonite is that it is non-caustice and does not injure the delicate gill filament as strong acids, saline or chemical mixtures did, and the loss of fish was due only to lack of vitality or injury from handling.

It is possible that Zonite will be very effective on any external parasite and I hope the scientific experts who study diseases and remedies for fishes, will look into the possibilities of this product.

Zonite can be had a great deal more cheaply than it is commonly sold in the drug stores, or "Dakin's Mixture," can be put up for you or made yourself as it is composed of Chlorine and salt water, I am told. The only difficulty with the "Dakin Mixture" is that it must be used within twenty-four hours, as it loses its potency from escapement of the gaseous content. Zonite is a patented product whereas the Chlorine may be held indefinitely.

After the fish were all treated and placed in another pond, I shut off the water and let the pond bottom bake in the sun for several days; then I went all over it with a sprinkling pot and sprayed it with the same mixture of Zonite and water. Since this treatment I have had no more trouble with the gill worms.

Since there has been no study made of this particular parasite in this country, a letter written from England, to a friend of Mr. T. F. Wilcox, Chairman of Fish Committee, South Side Sportsmens' Club, by Wilfred Rushten, may be interesting. He says:

"I have inquired further into the gill parasite 'Discotyle sagittatum' and find that it has a direct development i. e., that it produces embyros direct without passing through a second host. The eggs when hatched give origin to embyro with cilia which enables the embyro to find its way to other gill filaments and develop straight away, or they may swim about a bit and become attached to the body of some fish and gradually creep into the gill chamber and then develop into the full grown animal.

"I am unable to state definitely how they first get into a water containing fish but very probably by means of some mollusca as food.

"I have information of the parasite appearing in a hatchery due to the fish being fed on uncooked cockles and never appearing before or since when proper precautions are taken to see that the cockles are free from the parasite.

"A salt bath is said to remove the parasites but I have seen cases where the parasite itself withstood a saturated solution of salt and survived.

"In one instance I am aware of, all fish caught were submitted to a bath of ten per cent salt solution and the parasites removed then the fish were put back into the lake. Outbreaks of this parasite appear to be sporadic."

### *Discussion*

MR. LAIRD: Several years ago I had occasion to get some scallops; I thought they would be fine food for trout. From that letter and the fact that they had been studied in England, I believe that is the way I inoculated my water with this gill worm.

DR. DAVIS: I have not tried Zonite to any extent. Mr. Laird had such good results with it that I attempted to do a little with fingerlings, but possibly we used it too strong. The fish after treatment appeared to be all right, but the next morning they were all dead. Since we were rather in a pinch at that time, and I knew what would cure the disease, I did not follow it up any further. If it does work out successfully for bacterial disease, it will be a somewhat difficult treatment to handle, because when we experimented with it the fish apparently suffered no ill effects at the time, but they all died later, while those to which we gave some other treatment like copper sulphate appeared to be in a more serious condition when they came out of the treatment, yet the next day they were all right. There are one or two other reagents that I have been working with which act similarly: the fish come out apparently uninjured; two hours later they will die, and you cannot tell just what effect the treatment is having on them. For a man inexperienced in the treatment of fish, as most of our hatchery superintendents are, I consider a reagent of that type a rather dangerous thing to use if we can get something that will act somewhat different.

DR. BELDING: I wish to corroborate what Dr. Davis has said. In Zonite you are dealing with the action of chlorine, the same as you are with the so-called Dakin solution which is a neutralized hypochloride solution; and it comes back to the question of the toxicity of hypochloride of lime and chlorine gas. It has been my experience, as Dr. Davis has said, that the fish apparently come out of it and then die later. It seems

to me that you have got to look for a method that does not require, perhaps, so much work as to handle each fish individually, as Mr. Laird described. I do not think you could handle bacterial disease through any hypochloride solution; it will either paralyze the fish or kill the worm, but you certainly have to be very careful in adjusting the amount used in the water if you want to avoid killing the fish.

MR. LAIRD: There was no after-effect at all in the larger fish; why it should act on the smaller fish in that way I cannot say. The big fish picked right up and have had no further trouble with the worm. Probably it is not good for the smaller fish.

PRESIDENT TITCOMB: Would you be able to apply it in quantities, dipping a net full of fish at a time?

MR. LAIRD: No; if you apply the treatment that way the worm is so imbedded in the gill filament that the solution does not touch them.

PRESIDENT TITCOMB: You have to handle each fish separately?

MR. LAIRD: Yes, that is the only way I could get rid of them. The dipping method will get some of them, but not all.

PRESIDENT TITCOMB: It would be some job if you had many of them.

MR. LAIRD: Yes, it is no fun to handle three or four thousand fish that way, but it is better to handle them than to lose them.

# PRELIMINARY REPORT OF FISHWAY WORK*

By John N. Cobb.

*Dean, College of Fisheries, University of Washington, Seattle.*

The great number of hydro-electric projects developed, or projected, in the Pacific Coast states of recent years, have created grave fears on the part of those interested in the immensely valuable commercial and game fisheries of the coast as to their ability to safeguard same without too seriously hampering the legitimate demands of the former. And to this fear is added a growing suspicion on the part of the fishermen that some of the proposed projects have no actual economic demand behind them at present, and are pressed now because certain moneyed interests desire to get control of the best power sites at strategic points.

The chief danger to our fisheries from hydro-electric developments lie in the fact that the latter, in order to get the immense head of water needed to produce the power, are compelled to construct very high dams, so high in fact that the old type of fishway, which was generally inefficient even in dams of 40 or less feet in height, are absolutely useless in dams running from 90 to 300 feet in height.

The fishermen did not really awake to the danger, however, until an application was made to the Federal Power Commission for the right to construct a 90 foot dam at Priest Rapids, at a point on the main Columbia River where its waters passed through a comparatively narrow gorge. This application resulted in the calling of two conferences in the city of Seattle, Washington, in May, 1924.

The first conference was called for the morning of May 14th by the Washington State Fisheries Board, at the request of the Washington Irrigation and Development Company, which had applied to the Federal Power Commission for the permit to erect dam and do other work at Priest Rapids on the Columbia River, and which application had been contested by the fishery departments and the commercial fishermen of the States of Oregon and Washington at a hearing held January 8, 1924, by Col. W. J. Barden, U. S. A., head of the local district office of the U. S. Engineers' department. The purpose of the conference was to bring together the various parties interested in order to see what could be done toward safeguarding our migratory schools of fishes spawning in the Columbia above Priest Rapids.

*A comprehensive final report covering all phases of this work is in course of preparation and will appear as a Fisheries Bulletin of the University of Washington.

The second conference was called for the afternoon of May 14th, by Prof. John N. Cobb, Director, College of Fisheries, University of Washington, Seattle, acting for the university. In the call for this conference, which was issued before the one mentioned above was decided upon, attention was called to the rapid development of the demand for hydro-power, and the danger that unless immediate steps were taken to safeguard the annual runs of migratory fishes entering the rivers of the Pacific Coast, they would be destroyed because of their inability to reach their natural spawning in the upper reaches of the river or in one of its many tributaries.

The call goes on to state: "With the methods now in vogue for getting fish over dams it is questionable whether a fishway could be installed and successfully operated in dams over 30 feet in height, but it is possible that more extensive research by biologists and engineers in collaboration, which has not been done heretofore to any considerable extent, might solve the immediate problems, a summary of which follows:

(1) To get the adult fish up to their desired spawning ground.

(2) To get the adult trout and other fish over the dam in their migrations up and down the stream. The salmon all die after spawning and thus present no down-stream problem.

(3) To get the young salmon and trout safely down the stream and to their natural home in salt water—

- (a) Either over the dam or through the turbine.
- (b) Prevent their entering the irrigation ditches.

"Unless the problems noted above are solved, we must either sacrifice our immensely valuable river fisheries, or else prevent the building of dams and other obstructions in rivers frequented by these fish, thus forcing the hydro-power development into those sections of the rivers above where the fish spawn; and we feel sure that both interests involved would regard this as far from desirable and would welcome the devising of means by which the two can exist side by side without injury or unnecessary hardship to either."

The morning conference provided that a committee consisting of a representative from the Oregon Fish Commission, and

the Washington State Department of Fisheries, and Prof. John N. Cobb, Director of the College of Fisheries of the University of Washington, be appointed to represent the fishery interests.

At the afternoon session the same committee was appointed to represent the fisheries, while the following committee was appointed to represent the Northwest Electric Light & Power Association, an organization embracing the hydro-electric companies operating in the Pacific Northwest: O. B. Coldwell, of the Portland Electric Power Company, Portland, Oregon; J. E. Yates, of the Pacific Power & Light Company, Portland, Oregon; V. H. Greisser, of the Washington Water Power Company, Spokane, Washington; W. D. Shannon, of the Puget Sound Power and Light Company, of Seattle, Washington. The Washington Irrigation and Development Company, of Priest Rapids, Washington, was represented by J. E. Yates.

At the first meeting of the general committee, Mr. E. A. Sims, chairman of the Washington State Fisheries Board, was elected chairman, and myself, executive secretary. As it was felt that such a large committee would prove too unwieldly, an executive committee composed of one representative each from the Washington Department of Fisheries and the Oregon Fish Commission; J. E. Yates and W. D. Shannon representing the hydro-electric companies, and myself, was selected to have immediate charge of the work for the general committee.

At the first meeting of the Exectuive Committee, held at Seattle on June 12th, it was decided to fix the College of Fisheries, University of Washington, Seattle, as the headquarters, and that the research work to be undertaken would be carried out by and under the direct supervision of myself.

In order to provide funds for carrying on the work it was unanimously agreed to apportion the cost as follows: Oregon Fish Commission, one-fourth; Washington Department of Fisheries, one-fourth; and the remaining one-half by the Northwest Electric Light and Power Association.

### SELECTION OF SPOT FOR EXPERIMENT

As the original resolution under which the fisheries committee was appointed called for the work to be carried on at a dam now in operation, I visited various dams in the States of California, Oregon and Washington, and finally selected the Condit dam of the Northwestern Electric Company, located on the Big White Salmon River in Washington. This river is a tributary of the Columbia, and is located in Skamania and

Klickitat counties. It is about 30 miles in length. The river is of the usual type of mountain stream having a steep gradient, the banks occasionally narrowing into canyons. The Condit dam is about 4 miles from the mouth of the river, while the power plant is only 3 miles from the mouth, the impounded waters being carried from the dam to the plant through a 13 foot diameter wood pipe, and from there through a raceway into the river.

So far as known the species of migratory fish frequenting this river are the following: Chinook salmon (*Oncorhynchus tschawytscha*) and steel-head trout (*Salmo gairdneri*). It is said that a very few silverside salmon (*O. kisutch*) and Dog salmon (*O. keta*), also visit the river. The steelheads appear and spawn in the pools just below the dam during the months of April, May and the early part of June. The Chinook salmon and such other salmon as come into the river run during the months of September and October. While the steelheads are allowed to freely swim up to the foot of the, at present, impassable dam, the U. S. Bureau of Fisheries, which has a salmon hatchery on the Columbia River about a mile below where the Big White Salmon debouches into the main river, installs a rack a few hundred yards up from the mouth in September of each year and holds all the salmon here until they are ripe, when the fish are seined and towed in live boxes to the hatchery where they are stripped, the eggs fertilized with the melt, and put into the hatchery and held here until the young have been born and reached the proper age, when they are either planted in the Big White Salmon River or in Spring Creek, which forms the hatchery's water supply.

As near as could be learned from fish culturists and others familiar with the salmon runs in this vicinity, the Chinook salmon would, if permitted freedom of movement, spawn naturally on the gravel bars between the mouth and the power plant.

The reasons for selecting the Condit dam for the work in question were: (1) The convenient shape of the dam and the banks just below it for carrying on the work; (2) The fact that there was available a run of migratory fish in the spring and another in the autumn, the latter of which could be utilized this year; (3) The accessibility of the dam to rail and other transportation facilities.

## MIGRATIONS AND SPAWNING HABITS OF THE FISH

In order to properly understand the problems involved in this work it is necessary to review briefly what we know of the spawning habits of those members of the Salmonidae family found in our rivers.

All of the salmons spend the greater part of their lives in saltwater. When they reach maturity, this varying with the species and sometimes with the individuals, the schools gather in the salt and brackish waters off the mouth of the streams they intend to enter. The first one to appear is the Chinook usually in March, followed in the order named at later dates, by the steelhead, blueback, humpback, dog and silver. While each has a fairly well defined period in which the bulk of the fish enter the river and pass up, there is a constant overlapping of the early or late runs of the other species, so that during part of the season all five may sometimes be found together.

When the fish first reach the brackish waters the eggs and milt are but slightly developed, but the fresh water present soon causes them to increase in size and they continue to do so as the salmon slowly make their way up the river. It is well established that the salmon return to spawn to the stream in which they hatched out naturally, or where they were first planted and spent the early months of their lives and it is quite certain they would not spawn in any other stream should their access to this stream be cut off in the period between the time they went to sea in their youth and their return as adults.

From the moment the fish reach the mouth of the river they stop feeding and from this time until the final end practically no food enters their stomachs, the animal living on the fat it has accumulated for this purpose.

As the successive runs pass up the main river, detachments drop out when the mouth of the respective stream destination has been reached.

Upon arrival at its spawning ground which may be a month or two or even longer after it first entered the stream, the fish play around waiting until the eggs and milt are ripe. The fish excavates with its tail a broad, shallow "nest" in the gravelly bed of the stream in rapid water, at a depth of one to several feet; the female deposits her eggs in it, and then the male covers these with the milt, thus fertilizing them. The eggs work their way down into the gravel and are thus protected from their aquatic and bird enemies.

The long and fatiguing journey from salt water to the spawning grounds, during all of which time no food enters its stomach, and then the strenuous operation of spawning, in themselves would doubtless kill the majority of fish, were there not also a process of decay going on during the last stages which in itself would kill them.

The dead parents float down stream, sometimes in such numbers that as they decay their aroma is distinctly offensive.

The young hatch out in about 90 days, the length of time required, however, depending upon the temperature of the water. The young are born with a yolk sac, and they live upon the contents of this for the first 30 days of their lives. As soon as the sac is absorbed the fish swims to the surface and begins feeding upon the microscopic animal life which is found in such waters. The period in which the young remain here varies with the species, some starting down the stream early in the following spring, while others remain here from 12 to 16 months. Usually they can be seen working their way in enormous numbers along the quieter and shoaler waters near the shores, and it is during this migration that so many milloins of them are lost if carried into unscreened irrigation ditches (from which they are carried onto the irrigated fields), or are carried into the flume of power plants, or possibly are killed by being carried over very high dams.

Those of the salmons that safely reach salt water do not, as a rule, appear again until they have reached maturity and are ready to go through the same procedure as their parents did.

As stated previously, the steelhead do not die after spawning, those that escape their enemies returning to the sea and coming back in subsequent years to repeat the operation. The development stages of the steelhead eggs and fry are very similar to that of the salmons and their seaward migration is very similar, although at a little later period in the year.

## THE HOISTING DEVICE AND METHOD OF OPERATION

For a number of years the writer has given much thought to the matter of fishways, and during the last three years has had abundant opportunities to carry out various ideas in connection with his work along these lines for the Washington State Department of Fisheries. These, however, were mainly in connection with dams of less than 30 feet in height, where the salmon could be trusted to ascend the fishway themselves if it was properly located and built. Experience with dams

over 40 feet in height had shown that salmon, at least, could not be trusted to work their way up over them through a fishway unaided. With this in mind, it was felt that the only hope of finding a solution lay in the adoption of a method by means of which the salmon would be lifted by artificial means, and it was finally decided to do this with a skip hoist.

In order to work out the mechanical details of this part of the problem the Link-Belt, Meese and Gottfried Company, of Seattle, was consulted and their resident engineer, Mr. R. S. Drury, very kindly gave liberally of his time and talents, and what success we obtained mechanically was due largely to his efforts. Mr. R. M. Hoffman, manager of the company, was also very helpful.

In a preliminary report of this character it has been thought best to condense the mechanical and other details as much as possible, as the final report will deal fully with them. As a result, I will merely state that the device used was essentially a skip hoist with a basket or skip 54″ x 60″ with minimum depth of 2′ 6″, the basket to run on a track approximately 62″ gauge. As it was to be merely an experimental device, and be removed as soon as the work was completed but one basket was provided for and it was arranged to raise and lower this by means of a rope from the basket through a cast iron head sheave to the hoist proper, a 6 to 1 friction drive, the motive power to operate same being supplied by a 5 h.p. 220 volts, alternating current 3 phas, 1200 r.p.m. motor.

A wire basket was used because I had come to the conclusion that it would be better for many reasons not to lift any water, at least when Chinooks were handled. This was another violent departure from precedent, but the later experiments showed that this was a wise move. I was prepared, however, to line the inside of the basket with heavy canvas if this were necessary, but this need did not arise. The basket was made of galvanized wire, about 1½″ mesh, the idea being to have the mesh of sufficient width to permit of its emptying as fast as it rose from the water, and also that small fish could escape through the meshes.

As the experiments were for the purpose of testing out certain things and the apparatus was to be removed when they were ended, it was constructed as cheaply as possible. In order to save expense, the hoist was built from the pool to the ledge previously mentioned, and not up to the face of the dam itself.

It should be stated that in a permanent hoist a somewhat differently arranged apparatus would be used in raising the fish,

the above temporary makeshift being employed because it was cheap and easily handled, and answered the purpose sought at this time. The final report will treat of this feature quite exhaustively, as several methods were worked out for permanent installations.

At this point I desire to express my appreciation of the assistance rendered me by the Northwestern Electric Company through its chief manager, Mr. L. B. Merwin, Mr. O. L. LeFever, Chief Engineer, and Mr. David Shore, superintendent of the White Salmon plant, who had charge of the construction of the hoist.

The Condit dam was built about 1911 and is about 250 feet wide at the top. Owing to the shape of the canyon at this place the lower part is only about 164 feet in width. The top of the dam is about 121 feet from the ordinary water. The attached photograph will give a good idea of the general shape of the dam and the lay of the river and banks just below it better than I can describe it. Just below the dam and on the east side is an overhanging rocky ledge, the top of which is about 70 feet from the surface of the pool at the foot of the dam. A line dropped straight down from a break in this ledge would touch the upper side of a little bay cutting into the shores of the pool. This little bay had been partly excavated by the workmen who had built the fishway installed some time after the dam was built and which was later removed after the company and Mr. L. H. Darwin, then Washington Fish Commissioner, had come to an agreement for its removal.

As it would have been impossible to devise any apparatus comeptent enough to gather fish swimming freely in the pool at the foot of the dam (this was somewhat circular, about 150 feet in diameter, and about 12 feet in depth at the deepest place at the time the experiments were carried on), a large box was built on the shore with the following shape and dimensions: Face, 10 feet in width; side width at bottom, 8¾ feet; side width at top, 12 feet; depth, 12 feet.

It was made especially strong in order to withstand the pressure from the water to be enclosed in it, and was then launched into the water of the little square cove and held here between two large logs which had been bolted to the rocks on opposite sides of the cove, and held down here by being fastened to these and to 6 x 6″ beams laid crosswise. In the forward end of this box a spillway was constructed, the sill being about 1 foot above the water level. This spillway was made quite deep so that if the water of the pool should rise above the sill of

the spillway, the latter could be raised by putting in splash boards or nailing cross pieces on.

The idea of this box was that of the entrance to an old-style fishway, and was put in at the spot described, and as shown in the photograph, because the entrance of the old fishway had been here, and the testimony of those who remembered it was to the effect that the steelhead trout had freely entered it, and it was hoped that the same would happen with this box.

The hoist rails were so arranged as to run down to the bottom of this box, the back of it being shaped to fit the slope of the rails, and the size of the basket was such that when it got to the bottom of the railway—which would be the bottom of the box—it would be about 15 inches from the bottom, while the clearance on the front and sides would be 15 inches.

As the idea was to induce the fish to jump from the pool into the box, where they could be picked up by the basket, it was necessary to have a considerable volume of water coming out the spillway. In order to accomplish this a flume was built from the face of the sloping dam to the box, and the amount of water thus entering could be regulated by rude gates in the flume.

As the hoist, if installed on the face of the dam, would drop its fish into the water above the dam, it was necessary in connection with the experimental device, operated only to the top of the bluff, to install a large box there into which the fish could be dumped from the basket.

In operating the device the basket would be lowered down the hoist until it came to a rest in the water of the box about 15 inches from the bottom. It would be allowed to remain here for varying periods, from one to 25 minutes, then hauled up to the top of the hoist, picking up what fish it could on the upward journey.

The basket rested on two sets of axles and pulleys, each independent of the other. Upon nearing the top the forward set continued straight up the hoist, but the after set, upon which the basket rested was run off upon an inverted crescent-shaped track, which caused the basket to slowly tip backwards and when it reached a certain elevation the fish slide out of the basket and into the receiving tank previously described.

## RESUME OF EXPERIMENTS.

Owing to the meager supply of water in the river between the dam and the power plant at the time of the experiment,

due to the long-continued rainless spell and the fact that most of the water passes through a 13 foot diameter wood pipe, no salmon could swim up above the power plant, so other arrangements for obtaining a supply for the experiment had to be made.

For some years, now, the U. S. Bureau of Fisheries has each autumn been installing a rack and corral in the river near its mouth and holding all the salmon until almost ripe, when they are seined out and towed in live cars to the hatchery located on the shore of the Columbia river about a mile south of where the White Salmon river debouches into it.

Arrangements were made with the bureau officials for obtaining a sufficient number of salmon to experiment with, and on September 22nd, there was fitted up a 1½ ton automobile truck with a V-shaped metal tank which had previously been used in transporting cement. A large sheet of heavy canvas was put inside the tank and the ends and sides carried to the top of the truck so that the water would not splash out and the salmon would be prevented from jumping or being thrown out.

The truck was driven close to the river bank, and the tank filled with fresh water while the bureau's crew was hauling the seine inside the corral. As the seine was brought to the bank close to the truck the medium sized and smaller Chinooks—the greater part of whom were males—were picked out of the net by the tail, and then, while held by the tail with one hand and supported under the back with the other, carried to and deposited gently in the tank. As soon as enough had been put in the tank it was driven as speedily as possible to the nearest point to the dam, and then after wrapping a wet sack around each fish it was carried down the three stairways, two ladders, and a short journey along the pipe line, and then deposited temporarily in the tank of water at the head of the hoist.

In addition, I carried 6 salmon in an automobile. A small wooden box was placed in the tonneau of the car, and on the first trip three sacks were thoroughly soaked in water, and a salmon put head first into each one. The fish were then laid side by side in the box, and the car driven to the same place as the truck had been and the fish carried to the tank one by one and deposited in it. As the bag seemed to interfere with the breathing of the fish, the three brought on the second trip were laid side by side on a wet sack placed in the bottom of the box and a wet sack laid over them, and these arrived in better shape than the others.

The auto reqiured about 19 minutes to cover the distance from the corral to the vicinity of the dam, while the truck required about 21 minutes to make the same distance. About 5 minutes was required to carry the fish from the truck and car to the receiving tank and all appeared to have suffered no ill effects from the handling, despite the fact that some of them were so ripe that eggs or melt would run from them upon handling.

As the natural spawning place of the Chinooks was below the power plant, and as it was feared that the fish might work their way down stream if turned into the pool, a net corral was built to enclose the front of the fishway and stretched about 12 feet from the bank and parallel to it for some 40 feet. Unfortunately, however, owing to the milkiness of the water, due to the glacial silt, and the rockiness of the bottom, it was impossible to make it tight, and before the experiment was finished a number of the salmon had escaped.

In all some 70 Chinook salmon were brought up in the truck on the 22nd and 23rd, and the greater part of these were early sent down and part placed in the box and part in the corral at the bottom, a few being held in reserve in the upper box on the bluff.

From early in the morning of the 23rd the writer kept close watch of the lower box. About the middle of the forenoon one salmon jumped into the box and this was the only one seen to do so during the 23rd and 24th, although possibly some might have done so during the night, which appeared to be the time of greatest activity on their part. One small trout must also have jumped into it as it was caught later on in the basket.

About 11 A. M. the basket was first lowered into the box and the real experiment began. It was drawn up 5 minutes later and one salmon found in it. Several more lifts were made that morning with the basket submerged one minute each time without result.

In the afternoon 16 experimental lifts were made, the period the basket was submerged varying from one minute to 30 minutes, and in 8 of these fish were caught.

On one lift when 2 fish had been caught, the basket was hauled to the top, lowered again, then hauled up and back down on the final trip, and despite the fact that the fish had covered some 320 feet in the journey without touching water they were as lively when finally placed in the water as when they were first lifted out of it, thus conclusively proving the main point in the experiment that if the fish could be brought to a focus they could be lifted almost any height within reason,

with or without any water, and without any exertion or strain on the part of the fish.

On the 24th the experiments were continued as on the 23rd, varied with instructive experiments on the effect of a greater or lesser flow of water from the flume upon the movements of the fish in the box; speed of the basket elevator; movements of the fish in the corral, and others, all having a bearing upon various aspects of the general problem, but not necessary to discuss here. In the majority of lifts we caught usually one salmon, which is not surprising when the small number of fish remaining in the box is taken into account.

Late in the afternoon of the 24th the experiments were stopped, the device dismantled and stored away until next spring when it was planned to install it again and operate it during the Steelhead trout run, at which time the water would be high enough to permit the fish to swim up the river to the foot of the dam.

Eleven fish died during the experiments. Of these 7 lost their lives through jumping out of the upper box during the night time, one was caught in the net over the lower box, two were found dead in the lower box with every appearance of having been killed by the basket, while one was found dead in the upper box when the water was drawn off.

It is also planned to take up at that time the other phases of the problem—the getting down of the young salmon and trout, and the old Steelheads who have survived the journey, and the devising of means to keep them out of the irrigation ditches.

### SUMMARY OF EXPERIMENTS

The experiments carried on as noted above have developed certain facts:

(1) That if the fish can be induced to enter such a fishway, they can be lifted almost any height desired.

(2) That certain fish can be lifted without water, and the experiments conclusively proved this was a decided advantage, as owing to their being no water in the basket their struggles were extremely limited, while if they had been lifted in water some sort of cover to hold them in the basket would have to be devised in order to prevent their jumping out. Where needed the basket could be made watertight by lining with heavy canvas.

(3) That in the majority of cases this method can be employed in getting fish over high dams, provided an experienced

biologist, who is familiar with the habits of the fish sought to be lifted, is called in before work on the dam is started. This is absolutely essential as certain precautions must be taken with the bed of the river, etc., before and during the construction period, in order to persuade the fish to foregather in front of the entrance to the fishway or fish hoist.

## EXPERIMENTS WITH STEELHEADS

In the spring of 1925 the device was again hooked up and a few Steelheads entered the box and were taken safely up in the device, but owing to the very high water which prevailed during this season, during part of which time the box at the foot of the lift was completely submerged, the experiments were somewhat hampered during the short time the fish were available. It was conclusively proven that the Steelheads were not injured, as some fish culturists claimed they would be, by being lifted in the basket without water.

## BAKER RIVER LIFT

In 1925 the Puget Sound Power and Light Company began the erection of a 235 foot dam in the Baker River, a tributary of the Skagit River, in Washington. This company participated in the experiments noted above, and its engineer, Mr. W. D. Shannon, was a member of the committee charged with the work.

Baker River has the only run of Sockeye salmon (*O. nerka*) to be found in any Washington stream debouching into Puget Sound, and for many years the U. S. Bureau of Fisheries has operated a salmon hatchery, largely for these Sockeyes, at the head of the Baker Lake, a large lake about 18 miles above where the dam was to be built.

Although the company had promised to safeguard the runs of anadromous fish in this river at the time its permit was granted by the Washington State Hydraulic Engineer, no effort was made to do so until after the power plant had been constructed at a point nearly a quarter mile below the dam. This delay is largely to be attributed to the company's waiting until the White Salmon experiments were completed.

In the meantime, however, the contractors in clearing away below the dam threw so much debris into the canyon that the stream was blocked and when the fish appeared in 1925 they were unable to reach the opening which had been left temporarily at the foot of the partly constructed dam for them to

pass through. As a result of this experience it was found necessary to make some changes in the fishway plan.

The way up the stream above the outlet from the power plant was closed to the fish, and they were led around the upper corner of the plant. Here a small narrow fishway of the pool and fall system, about 35 feet in vertical height, was installed and the fish encountered no serious difficulty in working up it.

An excellent feature in this fishway was a metal screen fastened to the walls of the boxes and curved inward of the latter in order to prevent the fish from working back down again.

Passing out of the fishway the salmon entered a flume which carried them a distance of nearly 800 feet to the foot of a steep slope which led to the top of the dam. A small railway was built here and a metal car raised and lowered by means of an electric hoist.

The car would be lowered into the flume at the foot of the long incline, the top lifted and water and fish allowed to enter. The top would then be closed and the car slowly raised to a platform at the top. Here a trap door in the platform would be opened, disclosing a small flume leading down into the water above the dam. The car was fitted in the rear with a sliding door and when this was raised the fish and water would pass through the door and trap into the flume and thence into the lake.

The lift operated throughout the 1926 run of Sockeyes and lifted practically all of the Sockeye salmon that reached the flume, about 3,500. About 500 more were lost owing to injuries received in ascending the ladders, 8,219 Silver salmon and 175 Chinook salmon were lifted over the dam. Only a very small number of Steelheads entered the fishway.

It was an exceedingly fortunate thing that the White Salmon experiments could be put to a practical test so soon as this, although I feel that in future installations if the matter of the fish lift is taken into consideration from the very beginning, as it must be, and the necessary care in connection with the stream bed leading to the foot of the dam, etc., taken, a much more economical lift can be installed, than was the case with the Baker River dam.

The young fish coming down are allowed to pass over the dam and many did so with no considerable loss. Experience has shown however, that more experimental work will have to be done along this line.

I have carried out somewhat desultory, but quite encouraging, experiments in the passing of fish over high dams on their way down stream, but the publications of the results will have to be deferred until my final report is ready.

During the summer of 1926 Professor McMillan, an electrical engineer in Oregon Agricultural College, Corvallis, Oregon, carried out some extensive experiments in connection with electric fish stops at the Bonneville hatchery of the Oregon Fish Commission, but his report has not yet been published.

### *Discussion*

MR. WALCOTT: What weight will the humpback run?

MR. JOHN N. COBB: About four pounds. The chinook will run twenty-two, the silverside six, and the dog salmon about eight.

MR. C. B. TERRELL: Which is the better food fish?

MR. JOHN N. COBB: Each one is good; each is best for some certain purposes. Dog salmon probably furnishes the best smoked fish, while the finest canned fish is the Royal chinook. But we have chinooks that are off color, and as a result are sold very cheaply.

MR. DEROCHER: What is the approximate maximum weight of the humpback salmon?

MR. JOHN N. COBB: It is hard to say what the maximum weight would be. I suppose it would run to twelve pounds. The average, however, is four pounds.

MR. DEROCHER: In the spring of 1914 the United States Bureau of Fisheries sent a large consignment of humpback salmon eggs through to the eastern coast. I was superintendent of the station there at the time, having been sent there for experimental purposes. The humpback was chosen on account of the numerous barriers and obstructions in the rivers; the humpback is noted for not ascending rivers to any great extent for spawning purposes. These fish were placed in several of the rivers, and the Dennis River was the only one in which they really established themselves. While there were specimens from that river that would weigh as high as twelve pounds, we found the average fish there would weigh from two and a half to three pounds—that is, the average female fish; the average male fish would go a little higher.

In regard to fishways and the fish ascending the river, I wanted to verify your statement in regard to the pool. The State of Maine constructed a fishway just below a dam at the head of navigation on the Dennis River, and this fishway was taken from the upper end of the pool. Unfortunately, however, there was a spillway on the further end of the dam which came over a very flat ledge. Practically the first season that we operated there, when the humpbacks were two years old and came in to spawn, we had heavy rains; the water came from the spillway on the

corner of the dam so that it ran over this flat ledge and into the pool, about midway up the pool, and the fish, instead of going on up through the pool and over the fishway, took this water that came out of the spillway and landed up on this flat ledge below the dam. We had three men up there for nearly two days lifting the fish and throwing them over. In ordinary seasons it was hard work for these fish to ascend some of the gravel bars on the river; they would lie on their sides, flop weakly along, becoming bruised and very much emaciated during the ascent.

PRESIDENT TITCOMB: Were you going to ask a question?

MR. DEROCHER: I wanted to ask if the female fish out there died immediately after spawning?

MR. JOHN N. COBB: After they spawn naturally they all die immediately, or practically so. They do not feed from the time they enter fresh water, and their stomach and intestines are shrivelled up to such an extent that it would be impossible for the fish to digest anything, particularly following the exhaustion which succeeds that last act which is the culminating point of their lives. We do not have any doubt about it, because you can find their dead bodies in enormous numbers on and near the spawning grounds.

DR. HUBBS: I think we are to be congratulated on having the privilege of listening to this interesting explanation of the splendid work that is being done on fish chutes on the west coast. It is certainly an inspiration to us here who have to deal with dams which at the most are fifty feet high to realize that they have been able to get the fish over dams which are four times that height. Of course our problems here in fish chutes are very different, it seems to me. Perhaps we could not apply this particular method, effective as it might be, for two or three reasons. We do not have the same fish, in the first place; in the second place, our dams are not so high and the fish are not so valuable; there is no tremendous fishery dependent on our streams. It is very doubtful, therefore, whether we could put through legislation to require such an expensive operation to be carried out.

In Michigan, we, of course, have the same problem with fish chutes that all the eastern states have, and we decided a few years ago to give some attention to that in the way of investigation. Of course we had had reports from the power company and from the anglers and others that this particular fish chute let the fish up and this other one did not, but it was all hearsay evidence, so we decided to find out exactly what happened. We did this by inserting fyke nets in the top pocket of fish chutes in various parts of Michigan and actaully taking a census of the fishes which were able to make the ascent during the spring runs which we have. We found a few fish chutes of moderate height, say eighteen feet, that would let even a carp up, but in the case of our larger dams, running from thirty to forty feet, apparently these were ascended only by

rainbow trout. Brook trout and brown trout would not make it; bass would not; pike would make a feeble effort; suckers would make an effort and get perhaps fifteen or twenty feet, but the rainbow trout, steelhead trout, was the only fish which we found capable of ascending these fish chutes. Most of the fish chutes we had were the ordinary Cail type, a combination pool and fall system with alternating openings in the baffles—a large sized hole on the bottom. We wondered if only a few fish were able to make the ascent anyway, whether that bottom hole, with a big rush of water through it, was doing any good. So we closed these bottom openings with boards, so that we got the fall only from the top, and we got as many fish going up as we did in the first case, whereupon we decided to abandon these lower holes. It involved a big wastage of water anyway, and the power companies will appreciate that, I think. Our fisheries expert continued this investigation after we had gotten that far, and he has prepared a very short account of a new type of fish chute for Michigan. If there is time I would like to read this; it is just three pages. Will there be time, Mr. President?

PRESIDENT TITCOMB: Yes, I think we are interested in that subject now.

DR. HUBBS: This new type of fish chute is called the Holland-Metzelaar fish chute, a combination of the names of the biologist who suggested the idea and the engineer who perfected the mechanical details. This is the brief report which Dr. Metzelaar asked me to read on this occasion:

## THE HOLLAND-METZELAAR FISH CHUTE.

In the conventional type of Cail chute the water serves two purposes:

1. It creates a current below the dam which serves to attract fish and induces them to climb the steps.
2. It supplies the water in which the fish have actually to swim up.

The alternating openings in the baffles of the Cail chute create considerable churning, which makes it really difficult for the fish to ascend.

The new Holland-Metzelaar chute is based on the principle of complete separation of the two functions the water has to perform. The "attraction" water enters through a big gate into a 11″ to 12″ pipe which has fish-proof cratings at both the upper and the lower end. The water flowing through this pipe enters the chute in the lowermost pocket but one, flows over the bottom baffle and leaves the chute through the joint tail opening.

The fish, once having jumped on the bottom baffle and the powerful current rushing over it, have very easy going all the way farther up. The steps average about one foot. There is no

opening in the baffles except a 2″ cleaning hole. A film of water not more than 2″ thick cascades over these baffles from pocket to pocket. We make the pockets a little over 4 feet long. When the fish reach the top pocket they swim into the mill pond through a separate sliding valve. This valve has a small rectangular opening which is maintained at such a level that just enough water flows in to keep the pockets well filled. In other words the "mounting" water flowing through this small gate and the "attraction" water flowing through the main gate are entirely separate but for the lowermost end of the chute. Both gates are operated by rack and pinion. Three fish chutes of this type, more or less modified to local conditions, are now constructed and in operation on the Thornapple River near Grand Rapids, Michigan, and on the Menominee River near Chalk Hill. The first chute fully true to this type is now under construction on the Menominee River near White Rapids, Michigan. This chute will be equipped with spring leaders across the river. A test made at Ada on Thornapple River has shown that small-mouthed bass and mullet (*Moxostoma*) actually climb the chute."

Now that we are actually putting this into operation in Michigan it will no doubt be very interesting for the rest of the east coast to watch. Possibly we have partially solved the problem here.

MR. TERRELL: I wonder if Mr. Cobb would enlighten us as to whether sturgeon can be induced to climb any fishway. For example, the sturgeon no longer get over the dam at Shawano on the Wolf River in Wisconsin, and there has been considerable complaint about the dam on that account. I wondered if there was any kind of fishway that a sturgeon would climb.

MR. JOHN N. COBB: Well, that is a problem. We have been devoting our attention, of course, to fish that have the urge to go up, that have got to get to the spawning grounds. This is a pressing need with them and they are going to get up if it is at all possible. With fish that have no real urge to go up stream, we have thought it just as well to leave them below the dam as to have them above it, so we are not especially encouraging anything except salmon and steelhead trout to pass up. Your sturgeon, of course, would have the urge to go up, but I think probably the trouble is that they have practically all disappeared; anyway, they have pretty nearly everywhere else; they are practically exhausted from the streams. I do not see any reason why it could not swim up as well as any of the others. If black bass or mullet swim up your fishways, they ought to be encouraged to do so.

PRESIDENR TITCOMB: Our eastern sturgeon does not seem to want to ascend the streams any distance. They go into deep pools to spawn.

Dr. Hubbs: Quite a number of our fishes do have the instinct of ascending the smaller streams to spawn. It is true of nearly all of them to some extent, and very markedly so of some. For instance, the suckers. We may say, what is the use of letting the suckers up? Well, the sucker is now becoming one of the important commercial fishes of the Great Lakes, and in the future will in all probability take a leading place, provided we can give them a chance to ascend the streams to spawn. I may say that we have here detailed drawings, blueprints, of these fish chutes which have been put in operation; I will leave them out so that after the next paper has been disposed of, anyone may have the opportunity of glancing at them.

Mr. John N. Cobb: This is merely a preliminary report; I wanted to get it into the society's proceedings early. We are going to present a full report on fishways of the Paicfic coast, covering much broader ground and we will have much more extensive experiments to include in that. That report will be published probably in the course of a year. This, therefore, is merely a preliminary announcement on one phase of it only.

Mr. Radcliffe: I think it is well to keep in mind the distinction between the two classes, your anadromous fishes, which go up for the purpose of spawning, and your strictly fresh water fishes that simply tend to move back and forth in the stream. Would it not in any case be much cheaper, instead of building a fishway for a high dam, to put your money into fish hatcheries in order to keep those upper waters stocked in the case of the fresh water species?

Mr. John N. Cobb: It is hopeless to take care of salmon any distance from their natural spawning ground, because the fish are not in shape to spawn, so we do not figure on the others at all so far as the fishway is concerned. We have hatcheries scattered all over the Columbia valley—there are about ten of them, and they are handling mainly the trouts, and some few salmon. The hatchery is handling all the trout up there, so we do not worry about them.

President Titcomb: In other words, you do not believe in fishways for trout?

Mr. Radcliffe: I do not think Mr. Cobb understood my question. I was thinking more of basses and sun fishes, where you have quite a high dam, and the question of these fishes moving up and down over the fishway. Would it not be cheaper to put a hatchery above the dam to keep those waters stocked than it would to put in a fishway so that these fishes might move up or down the river?

President Titcomb: You are not talking about the Pacific coast?

Mr. Radcliffe: No, about the strictly fresh water fishes.

Mr. John N. Cobb: Bass and sun fish would have very little weight with us, because they are mainly down in the open reaches of the Columbia, and we are handling them now with hatcheries.

PRESIDENT TITCOMB: They ought not to have been put there at all. Mr. Cobb, I want to ask you if any of your fishways are covered, and whether the salmon will enter an entirely closed chute?

MR. JOHN N. COBB: The one on the Sunnyside dam is entirely closed. That was done so that the natives could not steal the fish.

PRESIDENT TITCOMB: They go up through that?

MR. JOHN N. COBB: Yes, but we did not succeed in our object; the natives get them just the same.

PROFESSOR BORODIN: May I inquire whether the fish are injured in any way during the course of the lifting operation that you have described?

MR. JOHN N. COBB: After we lifted the fish we dropped them into this compartment at the top, so we were able to examine all the fish that came up and to see whether or not they had been injured. We found none of them injured in any way.

MR. DINSMORE: Don't you know that in 1910 we lifted fish in a car 150 feet over the Elwah dam, then under construction—using the construction company's derrick for the purpose—held them above for three or four weeks during the spawning season, and took upwards of a quarter of a million eggs from them? This was all done fifteen or twenty years ago.

MR. JOHN N. COBB: We turned these over to the bureau, and the bureau took the eggs.

DR. HUBBS: When I was out on the Pacific coast last summer on the North Umpqua near Roseburg, Oregon, I saw a very peculiar type of fishway which local residents claimed was successful. It was an enormous pipe, like the stand pipe of a city water system. The dam was not high, about fifteen feet or so, but the inventor claimed that it did not matter how high the dam was, it would work the same way. The principle, as I understand it, was that of an electrically controlled lift inside this steel cylinder, with a very elaborate timing device so that the water would flow into this tube and out to attract the fish for a certain length of time; then at that given time the gate would close, and after the gate had closed the bucket inside, which occupied the whole chamber, would rise and the water with the fish would go over at the other end.

MR. JOHN N. COBB: I did not go into that, because we have not finished with it yet. The inventor of that hydraulic lift lives at Winchester. Two tests were made last fall. In one they failed because they could not get the fish, and in the other, the lift jammed, so they were going to try it this spring. I drove through there early in June and stopped off to look at it. They were going to have quite an elaborate test, but could not get things ready in time—the water was too high, for one thing, and as a result most of the run had gotten by. I am going

down again this coming autumn, and possibly we will be able to give the system a more thorough test. It is an hydraulic lift and it is still a question whether or not it will work. The lift is somewhat on the plan of the one that Mr. Leach invented. After the experiments this coming fall I shall be able to offer more authentic information about it. I may say that we are welcoming anything that will solve this problem in the cheapest and best way, and if this system will do it we shall be only too pleased. It is rather questioned, however, because of the great expense. It is going to be an expensive thing in the case of a 250 foot dam—although one man has devised a method by which he builds the pipe right into the dam. However, we will know better after this lift is given a proper test.

DR. HUBBS: I wrote and asked the inventor how he took care of the problem of debris coming in and jamming the apparatus, the power company not cleaning trash out of the pools, and all that; also how he had taken care of the problem of rise and fall of the headwater and the tailwater—which is also a problem with us. He failed to answer my letter so I do not know whether he has thought of these particular difficulties or not. In our small power plants here in the east, where there is a considerable rise and fall both of headwater and tailwater that is one of our worst problems. Possibly the solution will have to wait until someone invents a floating tail piece for the fish chute and a floating head piece that will maintain a constant head at the top and have the lower end so arranged that a constant condition will hold there also.

# A BROOK TROUT STATION IN THE WHITE MOUNTAIN NATIONAL FOREST

By A. H. Dinsmore.

*U. S. Bureau of Fisheries*

The York Pond, New Hampshire, Fisheries Station, auxiliary to the St. Johnsbury, Vermont, station of the Bureau of Fisheries, has been established for the purpose of obtaining a supply of brook trout eggs from wild and semi-wild fish, for the various stations of the bureau.

To make adequate preparations for the increasing demands of the future, it was, of course, important to select a locality where there would be little limit on future expansion. Fortunately, in the White Mountain National Forest the government already owned vast areas, containing some of the finest trout waters in the country.

Through the interest and cooperation of Mr. J. J. Fritz, formerly supervisor of the forest, after the careful examination of many localities, the region in the vicinity of York Pond, lying in the townships of Berlin, Milan and Kilkenny, was selected. A blanket-use permit was issued by the Forest Service to the Bureau of Fisheries, covering fully the development work necessary, and through the cooperation of Commissioner Bartlett of the New Hampshire Department of Fisheries and Game, the entire watershed of the West Branch of the Ammonoosuc River was closed to fishermen and reserved for the purposes of the bureau.

From the foregoing, it will be seen that York Pond Station is engaged in a special class of work, the production of brook trout eggs, mainly for other hatcheries, and not in the production of fish for distribution. Its hatchery, however, a very subordinate factor in its development, will be utilized for producing much of the brood stock of the station, and also in raising trout for local distribution. During the recent past, from 50,000 to 75,000 brook trout from this hatchery have been planted in the public waters of the main Ammonoosuc River. Many large surplus male trout are also planted in the river each year at the close of the spawning season.

Active operations were begun in the summer of 1920, when the Forest Service built a substantial bridge over the river from the Jericho Road to the old railroad line leading from West Milan to the base of the mountains, opening it as an automobile road to York Pond. Since that time, the development work has progressed as rapidly as available funds would permit.

The work so far has consisted of rather crude and inexpensive camps to house employees; an equally crude but perfectly serviceable hatchery with an "eyeing" capacity of three million trout eggs; a cement dam, power house, feed mill and carpenter shop at the outlet of York Pond; a diversion dam with a half mile of canal, turning Cold Brook, which naturally joins the outlet of York Pond, over the intervening ridges, through two large artificial ponds and into York Pond; retaining and handling races for brood fish; and rearing races and ponds for growing fish.

There is now under construction a large canal which will eventually bring all the waters of the West Branch through York Pond, with many acres of artificial pond development on the way. In diverting this stream, it has been possible to take advantage of the valley of a small tributary stream, falling less rapidly than the main stream. Thus, near the head of the small valley, which is lowest at this point, the two streams lie so close together that a slight excavation only 300 feet in length will bring the large stream to the small valley. By flooding the valley, just above the mouth of the stream, a large control pond has been secured, having about 30 feet elevation above the bed of the stream at this point. From this point a large canal has been excavated along the hillside to a cut in the old railway, bringing the water over the divide to York Pond. Under this canal are many natural pond bottoms which will be flooded.

The extensive pond system thus provided will be utilized for growing and retaining brood trout. Up to the present time, with the construction work under way, strictly fish cultural work has been largely of an experimental nature, studying local conditions, and adapting to them the methods which give promise of best results. Several hundred thousand eggs were shipped last winter, however, and the reports which have been received from them fully confirm the expectations as to quality.

Throughout the year, season after season brings its own activities. The spawning season begins in late September, and continues well into November. As this season approaches, the brood fish are picked up by means of nets and traps from the various ponds, and congregated in the spawning or handling races. These are long narrow ponds where the fish can be rapidly caught up for frequent handling.

At the outset the males and females are separated, and the females graded as to size. The females are then handled two

or three times each week, and the "ripe" ones selected for spawning. As soon as the ripe females have been selected a sufficient supply of males are netted to be in readiness as required.

There are about 10,000 acres of wild land in the area of the forest set apart for this work. There are some 25 miles of brooks in the area which are closed to public fishing, and will be utilized for the collection of wild fish for brood stock. Approximately 10,000 trout were collected from these streams this season, and transferred to the station ponds. The natural reproduction in these streams is expected to be sufficient for present needs, there being many miles of the streams which are never fished.

With an ample supply coming on each year, it has been found unnecessary to carry a stock of adult male fish, and at the close of the spawning season each year, these fish are either planted in local waters, or exchanged for commercial eggs, the fry from which are planted.

In the development of the station every effort has been made to obviate the necessity of close attention to the ponds and raceways. Practically all the smaller ones are constructed in seepage basins which contain a sufficient flow of water, independent of artificial supply, to care for any stock they may contain, should the artificial supply be cut off. The canals have frequent safety spillways, amply large to care for floods, and all screen outlets are of generous proportions.

While the fish cultural work at present is confined to the immediate vicinity of York Pond, there are many other sections of the area which afford the finest opportunity for an extension of the work, as the demand for an increased supply of eggs may make this desirable.

### *Discussion*

MR. DINSMORE: Some years ago I was directed to locate, somewhere in the great holdings of the government in northern New England a place where there could be developed a natural source for what we may call semi-wild brook trout eggs. As you doubtless all know, the United States government is probably the largest land holder in New England. controlling about half a million acres of wood and mountain land in the White Mountains of Maine and New Hampshire. It seemed that in those regions somewhere there would be an opportuinty where we could have control for all time of waters peculiarly adapted to the maintenance and development of those species of fish of which there is such a great demand for eggs of high quality. We spent about four or five years in find-

ing a suitable location, and some account of the work we have done there will be shown in the slides which I now present.

(The slides were here shown, with explanatory comments by Mr. Dinsmore.)

MR. ADAMS: What will be the total volume of water running out of this system during the drought period, say around the first of October?

MR. DINSMORE: Our lowest water comes in August.

MR. ADAMS: What would it be at that time, then?

MR. DINSMORE: I could not tell you. Our water supply is unlimited.

MR. ADAMS: I should judge that it would exceed that of any hatchery in the country.

MR. DINSMORE: Oh yes, there is nothing like it in the country.

MR. LEAVINS: Do I understand that you plant fry in the river, or in its tributaries?

MR. DINSMORE: In the river. Two years ago I travelled not less than 300 miles planting these fry. My theory, having in mind our observations on that artificial work, where we have all these fingerling trout and the fry with them, is that we have very much overrated the cannibalism of fish under natural conditions.

MR. HARDY: Did you ever plant any eggs?

MR. DINSMORE: We did plant eggs, spread over an area of two miles on the stream. This planting was done in the month of July, during the day time, under extremely warm weather conditions, in bright sunshine. The water within two miles of that stream rises in temperature from twenty to twenty-five degrees. We began by planting just where the stream drops out of the upper valley and we continued to plant at intervals until we reached the springs, which are the coldest I know of anywhere. A week later I dug into the first nest at the lower end, down to the level at which we had planted the fry, and I did not find anything. I was astonished, because I did not know where they could have gone to. I continued to dig, and eight or ten inches below the level that the eggs had been planted I found the fry, in a perfectly normal condition, with no indication of losses. We went on up the pool until we came to where we had left the eggs, and there we found them in perfect condition and just about to hatch. That is the only thing I could say definitely about the planting of eggs. We have planted other eggs, but I could not tell you what the results were.

PROFESSOR BORODIN: Was that in coarse gravel?

MR. DINSMORE: Yes. We had carried that forty miles on horseback. We stuck shingles down in the bed of the stream, then excavated the nest, poured the eggs in, and put the gravel back on—eighteen inches of it.

# LIFE HISTORY OF BASS CESTODE PROTEOCEPHALUS AMBLOPLITIS

By Ralph H. Bangham.

*College of Wooster, Wooster, Ohio.*

The damage done by the larvae of this tapeworm infesting bass has previously been discussed before this society by Dr. Emmeline Moore. She told of the encystment of this form in the mesentery and visceral organs. She emphasized the damage to the reproductive organs. Many bass are rendered sterile by a heavy infestation of this tapeworm. In at least six states hatcheries have had the reproduction materially lowered due to this parasite.

In Ohio this is a most serious handicap to the hatching of bass. Our bass breeders are obtained from Lake Erie. At times I have counted as many as sixty of these larval worms in a single egg sac. There were haemorrhagic areas about the worm and the eggs near the worm were small and soft. The testes are similarly affected. The tissue about the worm is fibrous and the organ has a knotted appearance.

These parasites reach the bass very early in the life of the fish and for several years I have been trying to find out how this infestation develops.

In 1923 I worked out the life cycle of another cestode of the same family. This form never encysts in the fish but after reaching the fish develops to sexual maturity in the intestine. I studied the problem chiefly by an examination of the food ingested and found that there were three minute crustacean forms which could carry the first or early larval stage of this small cestode. Two species of copepods and one species of cladoceran or water flea were found to be the intermediate hosts of this form.

A minute crustacean of the proper species eats the egg, the larvae emerges and penetrates the intestine and develops in the body cavity of this form. I have found many of these parasitized copepods in the stomachs of young bass and have seen them emerging from their first host as the copepod or water flea was digested. This species found in young bass and several other Lake Erie fish does slight harm.

This life cycle gave some clue to the possible life cycle of the larger form in the bass. In young bass measuring one to one and one-half inches long I have found tiny cysts of larval Proteocephalus ambloplitis outside the intestine along the mesentery. These measure .006 to .010 inch. More of these

parasites are obtained by the bass until they reach a length of about 2-3 inches when they do not obtain more. The ones they have grow rapidly but never attain maturity encysted in the fish. The infested fish must be eaten by a fresh water dog-fish or black bass then the larvae may attach to the upper intestine and grow to sexual maturity.

Until this summer I had not been able to find how the young bass obtain this worm. When studying young large-mouth bass taken from a lake at the headwaters of the Ohio River drainage system many of the P. ambloplitis cysts were found. In examining the stomach contents of this fish I found a cyclops type of copepod with the first stage in its body cavity. In the same fish these very small larvae were in the stomach or upper intestine. One was in the process of penetrating the intestine. The suckers are invaginated in the copepod. They push out and the tiny worm works its way through the intestine and to the mesentery or liver where a cyst is formed. The food of these young fish 1-1½ inches long was chiefly small copepods and nearly all the cysts in the fish were minute. Fish examined from this lake at frequent intervals have shown that none of these parasites were obtained after the fish were a few months old. Another and larger crustacean was found to be an intermediate host in Lake Erie. This form was Hyalella knickerbockeri. In about half these crustaceans examined cysts of the first stage of P. ambloplitis were found. It is probable that a smaller crustacean also acts as an intermediate host at Lake Erie as they obtain some of these parasites before the young bass reach a size to take as large a form as Hyalella for food.

The life cycle of this tapeworm has become established at several of the hatcheries. The copepod I found infested is a common form of hatchery ponds and if the breeders carry the adult of the tapeworm it is easy for the cycle to become established.

Thus far I have not found the parasite established in streams of the Ohio Drainage. It is in Lake Chautauqua and also in three small lakes at the headwaters of the Ohio Drainage—Long, Round and Odell's Lakes.

We are now studying the bass in streams flowing into Lake Erie. The survey has just started but in twenty-five bass examined from five Lake Erie rivers I have found no larval or adult P. ambloplitis. I have found another species of cestode which has a direct development from the first intermediate host. There is still a different species in the bass of the Ohio drainage streams.

P. ambloplitis is the only species of the seven tapeworms found in Ohio bass that does noticeable harm to the infested fish. We are going to try in certain hatchery ponds to obtain breeders free from this parasite and compare the results with infested fish in other ponds.

### *Discussion*

DR. EMMELINE MOORE: I would like to ask Dr. Bangham how he accounts for the fact that, if one stage of this worm is in Hyalella, he finds in the adult bass such a large number of flat worms?

DR. BANGHAM: You mean that Hyalella is not very common.

DR. EMMELINE MOORE: Meaning that Hyalella, so far as I have found it, is not so frequently an abundant bass food.

DR. BANGHAM: Hyalella is only one of the forms that carry it. I have found it both in Cyclops and in Hyalella, but it may be in other forms. I mentioned having found it in the copepod and the cladoceran. I think Hyalella only is of marked importance in certain regions, but it does carry it in the west harbor and east harbor of Lake Erie—that is where I found a great many Hyalella, and the fish much more parasitized than in any other place on Lake Erie. I do not think it is carried via the same form in all localities, but these are the two forms I found it in.

DR. EMMELINE MOORE: Still further, I wonder how the adult bass becomes so heavily infested when the period between the infestation in the young bass and the adult bass is so long—a year, or two years, or three.

DR. BANGHAM: When I examined the young fish I found that very large numbers of these cysts had come in at one time, then they developed in the fish and migrated from one organ to another. They do not get into the reproductive organs until later. They develop in the cyst and keep growing; then they migrate from these places to the other organs.

DR. EMMELINE MOORE: In some cases I have found several hundred small worms in the encysted stage, and it seemed almost impossible that the type of food as described should be the only source of infection. I am very glad to have that further explanation of it.

DR. EMBODY: I would just like to ask Dr. Bangham how long this parasite lives in the secondary host?

DR. BANGHAM: I am going to do more experimental work on that. I have not done any experimental feeding of these copepods; that is the next step, but from the work done in France on the experimental feeding of copepods by Doctors Jannica and Rosen, they develop in about three weeks and remain about six weeks.

DR. EMMELINE MOORE: I think it is a very splendid work that Dr. Bangham is doing, and he should be given every possible encouragement.

President Titcomb: That is the parasite you found in Mr. Beaman's hatchery, isn't it?

Dr. Bangham: That is the one, yes.

President Titcomb: This was discussed, I think, at last year's meeting. I would like to ask Dr. Bangham if the Ohio Commission has discontinued the distribution of these bass from Lake Erie.

Dr. Bangham: They have not. I am recommending that, but they have not done so. I have examined hundreds of bass from Ohio streams, both young and adults, and have never found it yet except in the head waters ,as I mentioned, of the Ohio River drainage. So far, in just starting the Lake Erie drainage, we have not found it there either, but all the bass from Lake Erie are infested with it.

President Titcomb: Do you think it is safe to take these fish any more for distribution purposes?

Dr. Bangham: No, and it is not profitable in the hatcheries to use these fish as breeders. They found that out; we had 150 Lake Erie breeders in one hatchery and did not get a single spawn.

Mr. Surber: May I inquire, Dr. Bangham, if you have found that same parasite in the crappie?

Dr. Bangham: We have not. It is found in the rock bass and bluegill, and maybe in the crappie; I have not examined for it.

Mr. Surber: In southern Minnesota we have obtained a great many crappies recently that have been infested with that, or something very similar. We have not been able positively to identify it.

Dr. Bangham: *Clinostomum marginatum*—the grub—is often confused with this parasite in the larval stage. They are sometimes found, too, in the visceral organs. They are usually in a watery cyst; the others are in a long, tortuous cyst with the white worm. Upon a superficial examination one is apt to confuse Clinostomum with this parasite, and the difference is sometimes only disclosed by more careful examination.

Dr. Davis: Mr. Chairman, I see you have got me wrong on the program; I had not any such ambition as to treat of all diseases of trout. That is altogether too long a story for an occasion of this sort. My paper refers only to one specific disease, the gill disease, on which I submitted a short paper last year at the meeting in Mobile.

# FURTHER OBSERVATIONS ON THE GILL DISEASE OF TROUT

By H. S. Davis.

*U. S. Bureau of Fisheries*

At the last meeting of this society, I presented a short paper on a disease of trout caused by a bacterial infection of the gills. During the summer of 1926, this disease caused considerable mortality among several lots of fingerling trout at the Holden, Vermont, experimental hatchery. However, the opinion was expressed at that time that the disease would not prove a serious menace to trout culture. Further experience with the disease during the present season has caused us to modify our views in several important respects.

It now appears that the disease may cause serious losses among both fingerling and yearling trout and I am inclined to believe that in many instances it may prove to be much more destructive than the flagellete, *Octomitus salmonis*, of which you have heard much during recent years.

Ever since the Holden hatchery was built heavy losses have occurred annually among the fry at about the time they were beginning to feed. At different times several investigators have attempted to determine the cause of this mortality but with no definite result other than to express the opinion that in some way the water supply was at fault. The hatchery is supplied with water from a large spring and also from a brook which flows through the grounds. Water from both sources is carried to the hatchery in underground pipes which are so arranged that the troughs may be supplied with either brook or spring water or a mixture of the two in any proportion.

Since the hatchery has been used for experimental purposes, it has been found that fry hatched in spring water did not suffer from the usual spring mortality but that in the case of those hatched in brook water the mortality is practically 100 per cent. This has been found to be true of eggs from several different sources so we must assume that the mortality was due in some way to the use of brook water. No satisfactory explanation for the total loss of fry hatched in brook water was obtained until last spring when it was discovered that these fry all contracted the gill disease shortly before or at the time the yolk sac was absorbed, and that this was undoubtedly the immediate cause of their death. This conclusion was borne out by the fact that no bacteria could be found on the gills of fry hatched in spring water.

Apparently, the bacteria which cause the disease are present in water from the brook but do not occur in the spring. Of course, this may be explained by the fact that trout of various ages are abundant in the brook while there are no trout or fish of any kind in the spring.

Some of the Vermont state hatcheries have experienced similar mortalities with trout fry hatched in brook water and, while no observations have been made on the gills of these fish, there appears to be no reason to doubt that the gill disease has been responsible for the mortality.

Later in the season another outbreak of the gill disease demonstrated in no uncertain fashion, that our previous estimate regarding its possibilities for harm must be radically revised. This time the disease appeared among a lot of 15,000 rainbow fingerlings which were being held in a small spring-fed pond. The disease broke out very suddenly and in three or four days from the time of its first appearance practically all of the fish were dead. Apparently these fish were infected with a very virulent strain of the bacteria since in all previous outbreaks among fingerlings the mortality had increased gradually and there was no sudden onset of the disease as in this case.

The pond containing the rainbow fingerlings drained into a similar pond immediately below containing 33,000 brook fingerlings which were in excellent condition until the outbreak of the gill disease in the pond above. Although these fish were immediately removed it was too late, and nearly all died from the gill disease within the next few days. Outbreaks of the disease also occurred in several other lots of brook trout fingerlings, but, taking advantage of our previous experience, we were able to check the epidemic before it had caused such serious losses as in the first lots to be attacked.

This summer the disease was not confined to fingerlings, as was the case last year, but also appeared in several lots of yearling brook trout and while the losses were not as heavy as in the fingerlings it is evident that the disease, if not controlled, is quite capable of causing serious injury to older fish.

As a result of our experience during the present season we are forced to the conclusion that the gill disease constitutes an important problem in trout culture, how important can only be determined after we have learned more regarding its distribution. Until very recently the disease was definitely known to occur only at the Holden hatchery although I do not think that anyone would be inclined to believe that the Holden station was unique in this respect. Some three weeks ago the

writer visited a hatchery near Barneveld, New York, to investigate a heavy mortality among fingerlings and yearling trout. It was found that the losses were undoubtedly primarily due to the gill disease since the bacteria could be readily demonstrated on the gills of sick and dying fish. One lot of fingerlings recently received from one of the New York State hatcheries was almost a total loss and since they began dying immediately after their arrival it seems reasonable to conclude that they were infected before their transfer to the Barneveld hatchery.

There is considerable evidence that the disease occurs at several hatcheries in New England and New York State, but it will undoubtedly be some time before we will be able to arrive at any definite conclusion regarding the extent of its distribution. This is largely due to the fact that the disease is so difficult to identify. The stricken fish exhibit no characteristic symptoms and, as I pointed out in my paper last year, the only certain means of diagnosis is to demonstrate the presence of the bacteria on the gills, and this can only be done by one familiar with the use of the microsocope. I have no doubt that obscure losses among trout which have been attributed to the water supply and similar agencies have, in reality, been due to this disease.

The only bright side of the picture is the fact that the disease can be readily controlled if the proper measures are taken before the fish become badly infected. Further experience with the copper sulphate treatment has fully confirmed our results of last year, that two treatments with a 1 to 2,000 solution of the sulphate will completely destroy all the bacteria on the gills. The fish should be placed in the copper sulphate solution for one minute and then quickly transferred to running water. If the treatment is properly carried out there will be very little loss unless the fish have been previously weakened by the disease. Unfortunately, the disease usually develops gradually and becomes firmly established before its presence is recognized. In such cases it is impossible to prevent considerable mortality since the gills have been so badly injured that many fish die even though the bacteria have been destroyed. On the other hand, we have found that if the fish are treated on the first appearance of the disease one dipping is usually sufficient, and the loss among the treated fish is negligible.

### *Discussion*

**Dr. Davis: We use a strong solution of copper sulphate—a solution which will kill the fish within a few minutes but which if used properly**

produces satisfactory results. We only dip the fish one or two minutes in this solution, and then remove them to fresh running water, and unless the fish are greatly weakened to start with, there will be practically no mortality. Of course if you hold your fish in there any length of time they will be killed; on the other hand, that brief exposure is sufficient to kill the bacteria. As I said, in some of the later outbreaks of the disease in which we treated the fish on the first appearance of the disease, the loss was negligible. As to the way we used it, we simply have a small hand net, dip the fish up into the copper sulphate solution, allow them to remain one minute, then take them out and put them in a trough of running water. It is surprising how many fish you can handle in that way in a few hours; it is really not as tedious a matter as you might think.

DR. EMMELINE MOORE: Do you sterilize the troughs before you put them back?

DR. DAVIS: In some cases, yes, but I really do not think it is necessary. One of the most remarkable things about this disease is that so far we have not had a recurrence in the same lot of fish. Even in cases where the disease has just started, one treatment with copper sulphate seems to be sufficient. Of course I do not want to say too much about that; we may have to change our minds in regard to it in the future, as we have already been obliged to do in a number of other instances. But so far we have not had a second outbreak in the same lot of fish, even though there was plenty of opportunity for them to become reinfected. They apparently become more or less immune to bacteria. It is rather a surprising thing that the treatment is as simple as it is, if taken in time. For this particular disease all that is necessary is the one treatment with copper sulphate. If the disease has got a good start it may be necessary to use two treatments in order to kill all the bacteria, and you will have considerable mortality in spite of the treatment. I have demonstrated to my satisfaction by careful microscopic examination of the gills that two treatments, even in the worst cases, will kill all the bacteria, but the trouble is that the gills have been so injured by the presence of the bacteria that the fish will continue to die several days after the bacteria have entirely disappeared from the gill. But if you take it in time, upon the first appearance of the disease, it can be checked with very little loss. The great difficulty, however, with the treatment of this disease is that it is so difficult to recognize. There are no characteristic symptoms that I know of; the fish simply get weak, turn over and die, and that is an end of it. In some cases especially last year, when we apparently had a more chronic form of the disease than we have this time—this time it has been more of an acute nature—the gill filament became very much enlarged and club-shaped at the end, and we could actually see that the outer edge of the gills was white, due to hypertrophy

of the epithelial tissues. But this year we have not had much of that, and I lay it to the fact that the fish were killed before the epithelium had time to grow. In most of the cases this year, too, all we could distinguish, aside from the presence of the bacteria on the gills, was that the gills were a little more slimy than usual. Of course in the dead fish you would find a tendency to detritus of various kinds collecting on the gills, and also a tendency of the gill filaments to become swollen at the end and to fuse together. After the experiences we have had I am able to tell by a glance through the microscope whether the gills are infected or not, but the only way to be certain whether you have the disease is to distinguish the bacteria, and unfortunately they are quite difficult to see. As I stated last year, the bacteria occur only on the surface of the gills. They form fine hairlike filaments, perfectly transparent in structure, so that you have to have a pretty good microscope and focus it very carefully in order to see them. When you do see them they form a fine mat or layer over the surface of the gill filaments, an almost continuous layer, which tends to exclude air and to interfere with respiration, as well as to irritate the filament, as is shown by the growth of the epithelial tissues as a result of infection.

Mr. W. H. Rowe: At what age does this disease usually appear with the fry?

Dr. Davis: We found some occurrences of it before the sac was absorbed, and then from that on. This year we have it in yearlings, so apparently it can attack them at almost any age, although it is undoubtedly most destructive of fry and the young fingerlings.

Dr. Embody: Is there any particular season at which it occurs?

Dr. Davis: No; last year our worst experience was during August. It broke out much earlier this year; the first occurrence was about the latter part of March or the first of April, on these young fry, then it broke out among the fingerlings along about the middle of June. We have things cleaned up now and we hardly have a case of it. Occasionally we will see a fish with it, but we are practically free from it at the present time.

Dr. Emmeline Moore: I discovered it in May at one of our hatcheries, where the fish were about an inch and a quarter long.

Mr. Derocher: Do you allow the fry to remain in the copper sulphate as long as you do the fingerlings?

Dr. Davis: As a matter of fact we have not treated any fish at that age yet. We only had a few fish in the brook water this year, and they died before we had time to do anything. We did not have time to adopt any control measures with them at all, so I do not know whether it would work in that case or not. But with the older fingerlings, say from an inch and a half to two inches long, the copper sulphate treatment will stop the disease if it is taken in time.

Dr. Belding: Have you tried any infection experiments by transferring infected fish to groups of well fish in other waters?

DR. DAVIS: No, we have not had an opportunity to do that yet.

DR. BELDING: It struck me from your description of your findings this year that possibly the disease was not one that spread readily from fish to fish, but that its spread depended upon environmental conditions.

DR. DAVIS: I think it will undoubtedly spread from fish to fish quite readily. Whether it will spread from one hatchery to another I am not able to say definitely. Of course we had the drainage from the pond that was first infected; it went immediately into the lower pond, where the brook trout contracted it right after it had appeared among the rainbows. I have no doubt in that case it was carried down to these fish from the rainbows. You will first find a few fish dying with it, the next day there will be more, and so on, so that apparently it is spreading. I do not think, however, that the disease develops quite as rapidly as it appears to do; the bacteria grow rather slowly on the gills and until they get numerous it is almost impossible to distinguish them. I am under the impression very definitely from what I have seen that the bacteria do grow rather slowly on the gills, but the fish show absolutely no symptoms of any injurious effects until they become very abundant; so that while it appears to break out very suddenly, as a matter of fact it has been developing for some time.

MR. GRAHAM: About the method of administering the treatment, I had some solutions made at the drug store. I told the druggist I wanted one to two thousand, and he put it in vials with a very small amount of water. I think that is the best way to get it in quickly without raising the temperature of the water while you let the little granules dissolve. The first treatment we kept in a minute, and the fish were about three inches long. Immediately on putting them back, or soon afterwards, they commenced to run with their noses out of water for about half an hour, then they quieted down and I did not see any loss or any distress after that. Then at another hatchery I tried the same solution on fingerlings about two inches long, but it was nearly a week after; I used one of these same bottles and I was surprised to see no distress at all. The fish did not act as if they had been in any bath; they just went back into the water, did not put their heads out of the water, and there was no loss. So that what I am coming at is this: will that stuff deteriorate with a very small amount of water?

DR. DAVIS: I do not know about a small amount, but it will if you use a considerable amount, especially if the water contains organic matter, or if it is hard water. These preparations are based on thoroughly pure water, not too hard. Of course we have some lime in our water, but not a large amount.

MR. GRAHAM: You would think possibly it did deteriorate?

DR. DAVIS: I think so. A better way is to buy it in the powdered form.

MR. GRAHAM: That will dissolve quickly?

Dr. Davis: Yes, almost at once.

Mr. Graham: I used the druggist because I was not sure of my scale, but I suppose I could use him just the same to put up a powder.

Dr. Davis: Well, it is very simple with the use of powder, because if you once weigh out the amount you want, you can use a glass dish, a vial or something of that kind, to measure it after that. You do not need to weigh each sample after you once have the one sample weighed out carefully; you can just measure the rest.

Mr. Adams: It seems to me that in the discussion of all these fish diseases we attempt to apply a remedy after the disease becomes thoroughly established. Now if here is a disease you cannot recognize in its earlier stages, I am wondering whether it would be worth while to consider applying some kind of preventive or taking some precautionary measures before your disease gets a hold. In other words, Dr. Davis, if you have any reason to suspect that in a hatchery you might be affected with this disease, would it be worth while to immerse all your fish in such a solution as has been described, simply as a preventive measure?

Dr. Davis: I rather think it would. Another year when any of our fish come out into raceways we are going to put them in a copper sulphate bath before they get the disease, or whether they have the disease or not. We did try that in one case this year. It is not at all conclusive, but some fish from the same eggs as the lot of rainbows in which we had a total loss, we put them out in a raceway below some brook trout which had had the disease but had been treated for it, and they have not developed any trouble. Of course that does not amount to very much, but it would appear there was an opportunity for them to become infected, becaues they were receiving drainage water which had previously flowed from raceways in which these brook trout which had previously been treated for the disease were being held. and we know they came from the strain of fish which were very susceptible to this disease.

President Titcomb: I would like to ask Dr. Davis if in the case of treatment for other diseases like gyrodactylus he would think it necessary to disinfect the pools before returning the fish to them?

Dr. Davis: I should say not with gyrodactylus; there is no evidence that they live off the fish for any length of time, so far as I know. Of course in the case of some bacterial diseases it would be advisable, there is no question about it. I doubt if it is necessary in the case of gyrodactylus.

President Titcomb: We have dipped every fish in this hatchery at the fingerling stage, and have taken others out of the pools for gyrodactylus, using acetic acid.

# FISH DISEASE EPIDEMICS

David L. Belding

*From the Evans Memorial and Boston University School of Medicine*

The extensive destruction of fish is by no means an uncommon occurrence in both fresh and salt water. There is scarcely a month in which one or more instances of such loss are not reported to the various state fish commissions. At times the destruction because of its severity assumes considerable importance.

The many and varied causes which bring about the death of fish are not always evident. Diagnosis, at best uncertain, is rendered difficult in most instances by a delayed examination in which postmortem changes may mask pathologic conditions and a changed environment may present no evidence of previous unfavorable conditions.

Fish destruction results either from an adverse environment or from disease. The former is more frequently the offender, because of the variety of conditions destructive to fish life, such as sudden changes in temperature, diminished oxygen, increased carbon dioxid, organic acids, poisonous gases, and the harmful substances in trade waste pollution. The infectious diseases are caused by animal and plant (bacteria) parasites. Since animal parasites rarely produce epidemics, except in overwhelming infections, this discussion is limited to diseases of bacterial origin; and a single disease, fish septicemia, commonly known as furunculosis, an infection due to B. salmonicida has been selected for illustrative purposes.

## ECONOMIC CONSIDERATIONS

Notwithstanding the fact that diseases destroy fish in appreciable numbers and render them unfit for food, they are rarely dangerous to man, although unfavorable publicity regarding parasitic infections of fish has injured the fishing industry. Nevertheless diseases are of particular interest to commercial fishermen and fish culturists. Epidemics at fish hatcheries cause serious financial loss. With fish septicemia the actual loss during a single epidemic is not the worst feature of the disease. Many hatcheries find it so difficult to eradicate that its elimination is practically impossible and fresh epidemics arise whenever conditions become suitable. Since these hatcheries often supply fish for private preserves where the fish are confined to a limited range, they serve as foci for spreading the disease. They are

less dangerous for stocking waters with a wide range, where the diseased fish are more widely separated and may die without infecting others.

In the past epidemics have been common in hatcheries but they have not been reported, either because they were unrecognized or through the fear of injuring the reputation of the hatchery. For the latter reason both private and government hatcheries have concealed losses caused by disease. The owners of private hatcheries have done so because of the market; and superintendents of government and state hatcheries because they felt that the presence of a disease reflected upon their reputation as fish culturists. As a result, few diseases have been reported and a corresponding loss of knowledge concerning the methods of combatting such diseases has resulted.

## OCCURRENCE

A review of fish literature reveals that epidemics of bacterial disease are more prevalent in nature than is ordinarily believed. Fish septicemia has been reported in open waters in Bavaria, England, and Ireland. Owing to the conditions produced by domestication, which are favorable to the spread of disease, epidemics are more prevalent in hatcheries and preserves where fish are held in restricted quarters. An example of this fact is the recent rapid increase of fish septicemia among the hatcheries of the New England and Middle Atlantic States.

## CONDITIONS FAVORING EPIDEMICS

Fish epidemics are similar in character to those affecting other animals, with the additional disadvantage of an easy means of transmission through the medium of water. Epidemics arise when circumstances are favorable for the rapid spread of the disease. Increased virulence of the causative organism, conditions suitable for its growth, lack of resistance on the part of the fish owing to an unfavorable environment, and easy means of transmission are the predisposing factors.

Epidemics of bacterial origin occur most frequently in warm weather, since the growth of the organism is stimulated and the resistance of the fish is lowered by high temperature. Unfavorable changes in environment, as trade waste pollution also lower their vitality. Since contact increases the ease of transmission, epidemics more frequently

occur in those species which school in large numbers. The fresh water species which, except at spawning time, are separated in small groups are less likely to suffer from epidemics.

Domestication has brought about changes which render fish more susceptible to epidemics by producing anaemic fish with lower vitality than in nature. Nevertheless exposure to disease may eventually produce, as in man, a reduction of susceptibility, and by selective breeding hatchery fish with a relative immunity to disease may be obtained. Under domestication conditions not found in nature, such as overcrowding, lack of exercise, and artificial food favor the spread of epidemics.

Overcrowding is dangerous for two reasons. It increases the chances of contact transmission and it lowers the general vitality of fish. There is a natural tendency for fish culturists optimistically to increase the number of fish per unit water space on the basis of former successful yields, until the point of safety is passed. Entrance into this danger zone forecasts possibilities of loss.

Under natural conditions fish have unlimited range and large vigorous fish are usually found in the larger bodies of water. In their constant search for food they obtain more exercise than in the restricted quarters of hatchery pools, where lack of exercise tends to produce logy fish of low vitality. Wild fish are forced to subsist on natural animal and plant food. In hatcheries they receive a less varied diet with little or no exertion upon their part. Hatchery food, apparently satisfactory in itself and fattening, may lack certain nutritional substances found in natural food. More important than the kind of food is overfeeding, the prevailing fault at some hatcheries.

## COURSE

In an epidemic of fish septicemia at a state trout hatchery the source of the disease was infected fish food. The disease obtained its start in the previous September but lay dormant until November, when an increasing death rate was observed among the large trout. During stripping the disease was spread by distributing infected fish to uninfected pools. The weekly death rate during November and December rose from 0.5 to 2.36 per cent and then fell in February to 0.85 per cent. No special attention was paid to the disease at this time except to separate the diseased fish from the well.

In the latter part of March when the temperature of the water had reached 45 degrees Fahrenheit, the disease began to assume epidemic proportions and the mortality rose in April to 3.08 per cent at a temperature of 49 degrees. During May the weekly death rate increased to 11.29 per cent and during June to 13.77 per cent, attaining its maximum height during the week ending June 6 when the water temperature had reached 60 degrees. During July the mortality declined to 5.5 per cent, owing to the reduction in the stock from 25,000 to 3,700. Owing to the radical measures employed to eliminate the disease, it was impossible to obtain further reliable statistics. No evidence of immunity was observed in the surviving fish.

## REMEDIAL MEASURES

The remedial measures fall into two groups: (1) handling an epidemic which has already started and, even more important, (2) the prevention of epidemics.

The first essential in handling an epidemic is a rapid and correct diagnosis, since a knowledge of the causative organism frequently suggests a curative or palliative measure. If a diagnosis of a particular organism can not be made the following general measures should be followed:

1. All infected and exposed fish should be destroyed.

2. The pools where the disease is present should be isolated. Unfortunately the serial construction of pools in most hatcheries renders this important measure impossible. Isolation includes complete separation as regards implements and attendants; or, if the latter is impossible, special precautionary measures on the part of the attendants.

3. The pools and surrounding ground should be sterilized by cleansing, chemical disinfection, and protracted exposure to sunlight. Provisions for the sterilization of implements in contact with infected material should be made.

4. The feeding should be reduced or even eliminated. Diseased fish apparently do better if they are not fed.

5. The temperature of the water should be lowered below 50 degrees Fahrenheit.

6. The relative flow should be increased by lowering the water levels in the pools.

Disease prevention requires the establishment of conditions which will maintain the vitality of the fish, and the

construction of hatcheries designed to reduce the possibility of disease transmission.

In order to maintain a virile resistant stock of trout the following rules should be followed:

1. Do not overcrowd. Keep the stock below the maximum number which may be accommodated.
2. Do not overfeed. Use no raw fish food.
3. Maintain a moderately low water temperature.

A hatchery in which epidemics may be handled successfully requires the following conditions.

1. Pools should be constructed with emergency outlets and inlets, so that each pool can function as an independent unit.
2. Pool construction should permit easy cleansing and sterilization.
3. The water supply should permit the mixing of warm and cold water so that any desired temperature can be maintained.
4. Provisions should be made for sterilizing and cleaning implements.

DR. BELDING: Dr. Davis' paper gives a definite method of handling a definite disease. Such knowledge would have come years ago if we had talked among ourselves about the diseases that occurred at this place or that place, but by keeping silent about them we have held back the development of methods of handling these diseases, and today we are not as far advanced as we should be. I think that in the next ten years you will find surprising changes in the methods of dealing with fish diseases.

In connection with the work of Dr. Davis, there is a case where diagnosis points to a definite remedy—copper sulphate. If a person could make a diagnosis quickly and immediately of that disease, he would know that copper sulphate was the proper treatment whereas copper sulphate would not, perhaps, be the proper treatment in another disease such as the one we have been using for illustration.

In the matter of sterilization, I must confess that I am rather uncertain as to the best type of pool. I do not know whether a cement pool offers an easier proposition for cleansing than certain types of board or dirt pools. Perhaps a cement pool, with a smooth surface which does not permit the harboring of organisms would be the easiest to sterilize or clean.

MR. ADAMS: To what extent is the cleaning of pools a factor in connection with either the origin or distribution of a disease of this kind? In other words, in one of our hatcheries we have had this experience,

that we are not cleaning the pools this year, or are cleaning them very seldom. Where previously these pools had been cleaned on the average of about once every week or ten days, we are now adopting a different practice. It would seem that by disturbing the bottom less than we did in previous years we are getting better results with the trout.

DR. BELDING: The sterilization of the pools in this particular disease, furunculosis, is, I think, absolutely necessary for complete eradication of the disease. In other diseases I think that the sterilization—and by sterilization I mean any cleaning, exposure to sunlight, the treatment of the pools with chemicals, is not as important or not as necessary as we have been led to suppose. It depends entirely upon the particular type of disease. Naturally it is very much more important in bacterial diseases than in other diseases, but I do think we perhaps have overemphasized that particular point. In regard to the frequent cleaning of pools as a matter of routine, which I gather Mr. Adams intended in his question, I think there is no particular need of frequent cleaning of the pool unless there is a deposit of sufficient organic material to have the condition of the water warrant cleaning.

MR. BITZER: You spoke about not feeding anything but what was boiled; I suppose that was to kill the germs. Would the boiling of foods be equal to feeding them raw—say, liver?

DR. BELDING: I made the statement that in this particular disease, furunculosis, it was dangerous to feed raw fish food. That statement applied only to fish and to no other food. Cooked fish would not have, perhaps, as high a nutritive value as raw fish. I do not know enough about the subject to give you any more than a general answer of this kind. I do feel that the advantage of being safe from disease would more than outweigh the advantages of feeding fish as food, particularly when you have other foods besides fish which can be used.

MR. GRAHAM: How about freezing; does that kill any of the germs?

DR. BELDING: Freezing in this particular disease does not; the organisms will grow in culture media at ice box temperature, which is about eight or ten degrees centigrade, and they will grow at their optimum at room temperature. They will die if held more than a few days at our body temperature, and that is why this particular disease is of no importance in regard to any possible danger to man—it could not live at body temperature. It is also of importance in the transmission of this disease by water fowl, because bird temperature being higher than that of man, the organisms would probably perish before they passed through the intestinal tract. But the disease could be, and probably is, transmitted by water fowl merely by contact—carrying material on the feet.

# DISEASES OF FISH IN OHIO HATCHERIES

By Ralph H. Bangham.

The conditions discussed in this paper are the result of a survey of the hatcheries in Ohio for the Division of Fish and Game.

Ohio has ten inland hatcheries, two more now under construction, and three small hatcheries controlled by local clubs. The fish hatched are chiefly large and small-mouthed bass, blue gills, and catfish. The breeders for the bass and catfish are obtained from Lake Erie.

Nearly all the parasites have already been found in many other regions and methods of treatment given. I will summarize the ones which do the most damage to our fish.

## PROTOZOAN PARASITES

Ichthyophthirius disease caused a large amount of damage especially to young small-mouthed bass in two of our largest hatcheries the past two years. This is called "itch" or "white spot disease" by goldfish hatchery men. The disease has been described many times; by Prytherch, Guberlet, Plehn and others. Most of you are acquainted with this infestation.

In the Newtown Hatchery, near Cincinnati, there were from 1-20 of these small white cysts on each young small-mouth examined June 14. The fish measured about 30 mm. There are six ponds in this hatchery, all fed by springs at the upper end. The infestation was first noted in the upper pond where goldfish had been wintered but removed two or three weeks before the fry were placed in the pond. In about six days after the heavy infestation was seen in the upper pond the bass in the next pond showed marked symptoms of the disease and ponds No. 2 and No. 3 were drained. The upper pond had been drained previously but most of the fish were too weak to handle or treat. Pond No. 1 was limed and after it had been dry a short time was filled. I treated 5,000 of the young bass with a 5% crystalline alum solution for one minute. All but the deeply embedded parasites were killed. These treated fish were placed in Pond No. 1 where, in a short time, all recovered and there were no more losses. All the rest of the young fish were transported to streams, some being treated and some untreated.

At another hatchery the disease was discovered at about the same time but was fairly well distributed throughout the nursery ponds. Fry had been distributed from this hatchery to three other hatcheries and at the two where small-mouth bass

had been taken the young fish were found to be infested. Examination was made for all possible sources of the disease and it was found on fish in an upper spring pond which had no visible flow to one of the breeding ponds below. Many young perch were found which had come through in some way from this pond and when the pond was drained a large amount of water was found seeping through. The fish which were heavily infested and from which these protozoa reached the fry were common sunfish, pickerel and goldfish.

All of these fish will be treated and moved to some other place—if not a pond entirely away from the hatchery, to the last pond the water flows through in the hatchery system. The ponds will all be dried and limed. Only these two hatcheries have been troubled with this disease and it is hoped by treatment of the ponds and by examination and treatment of new fish brought in to prevent this trouble another year.

Another protozoan parasite causing trouble to large-mouth bass in one hatchery is Cyclochaeta, a small disc shaped cilliate form. This organism has only been reported once previously in this country as injurious to hatchery fish. In 1926 Guberlet describes the damage done by this form in Washington State.

In the Ohio hatchery affected fish were found to have a glossy scum over their bodies. Most had a raw area on the top of their heads. Many parasites were found on the fins and gills. The fish became very sluggish and just before they died were on top swimming very slowly and gasping for breath. The water supply was increased and the pond was emptied in a few days. About one-third of the fish had died but yet the fish were crowded. These parasites were found on large-mouth bass at two other hatcheries but did little noticeable damage.

Another protozoan of the young large-mouth bass is a sporozoan form causing what the hatchery men call gill congestion. Many white cysts are found usually near the base of the gill filament. There are congested areas often just below the cyst. The gills become light in color, and badly infested fish come to the top and swim about in a weakened condition. These parasites do not affect the small-mouth bass to any extent. They are a species of the sporozoan Myxobolus.

A protozoan causing a tumor-like growth on the catfish is being studied. These papillary growths appear chiefly about the mouth and on the head. The organism found is a large oval binucleate cell—but this may be only one stage in the life cycle of this form.

Another protozoan often appears after the primary infestation of these other forms. It completely covers a fish and often appears to be the cause of the trouble, but is only secondary. It is a short-stalked, bell-shaped organism commonly found attached to cyclops in the spring. It is Rhabdostyla vernalis.

## PLANT PARASITES

Two bacterial infections have been studied. One found on catfish causing raw ulcers about the size of a dime or quarter is caused by a bacillus which is motile and a spore former. I have cultured it and inoculated a well fish. The other bacterial infection is not caused by a specific organism. Many bass breeders go blind because the cornea is injured by the knots of the trap nets and an infection sets in.

The other plant parasite is the fungus Saprolignia. I do not have time to discuss losses due to this but they are serious to breeder fish transported in the spring.

## FLATWORM PARASITES—FLUKES

The intestinal or stomach flukes do but little damage to the young fish.

Gyrodactylus is a very small fluke less than 1-25 inch in length with a large posterior disc having 16 small hooks and two large central hooks. It is found over the skin of the fish and often destroys large areas. It often attacks catfish and goldfish. The acetic acid treatment was very successful with these forms.

Another fluke is found on the gills and in the mouth of nearly all young large-mouth bass examined. It is slightly larger than Gyrodactylus, and has four eye spots. This fluke is Ancyrocephalus. It is not usually found in sufficient numbers to cause harm, but occasionally thousands are found in the gills of one fish. The acetic acid treatment kills these.

A fluke which infests the flesh of fish in its larval state has not been established in any of our hatcheries but it is found as the "grub" of bass and several other fish in many streams. In one small stream, Lost Creek, every bass is infested. Some have thousands of these larval flukes in their flesh. As the parasites develop many are lost for the cyst becomes soft and they break out.

## CESTODE PARASITES

Only three species of cestodes have been found in the hatcheries and Proteocephalus ambloplitis is the only one doing

harm. This form is discussed in another paper. There is another species harming the catfish to some degree—Acanthocphala parasites.

There are two species of these thorn-headed worms affecting the bass. In young bass the worm works through the intestine and encysts in the body cavity. The species which encysts is Echinorhynchus thecatus. This species is the one most often found in the upper intestine and pyloric caeca of small-mouth bass. It is sometimes in sufficient numbers to harm adult bass.

The other form, Neoechinorhynchus cylindratus, is more often found in the large-mouth bass. The species is never found in very large numbers in the host. The large-mouth bass may also have the E. Thecatus.

NEMATODES

These parasites are of minor importance to hatchery fish. Sometimes bass in Ohio streams have a heavy intestinal infestation.

There were several other species of parasites which infest the fish but none were well established in any hatchery. With some of the parasites cited more adequate methods of control need to be developed. We hope to make one hatchery chiefly experimental and study more fully life histories and control methods.

*Discussion*

MR. HAYFORD: I have no questions to ask, but I would like to say, after attending all these meetings of the American Fisheries Society, that the three papers we have just had on the diseases of fish are, I think, three of the greatest papers we have ever had along these lines, because in many instances they give us the cure. They have not only named the disease, but have offered a cure in most cases. It gets us back to where we have been trying to get, and what I believe every fish culturist is soon going to realize that he must have the services of one of these scientists, or, we might say, he must consult the experts. When you stop to think that we have one in Ohio, Massachusetts, New York, and so on down the line, if we will keep records of our mortality, so that there will be authentic figures to work on, we shall go ahead much faster than we otherwise would.

MR. BEAMAN: I would like to add a little of our experience at the Waramaug bass hatchery in regard to the disease evidenced by white spots on small-mouthed black bass fry. We lost thousands of bass from this disease through not knowing just how to deal with it. Dr. Emme-

line Moore diagnosed this disease as Ichthyophthirius. Our tanks are so situated that no water passes from one to the other; it is drawn from the general supply which comes from the lake. This year, before we placed any bass in these tanks, they were treated with a lime treatment. We used the spray, giving them a thorough spraying of this lime treatment and allowing them to be exposed for several days, after which they were filled with water and our fry were placed in the tanks. Following that there was no sign of the disease, so it would appear that prevention would be better than treatment after the trouble had occurred.

DR. DAVIS: I was specially interested in Dr. Bangham's reference to Cyclochaeta affecting bass, because I do not believe there is a hatchery in this country—and that includes all the hatcheries as well as the pond stations—in which Cyclochaeta does not occur; and yet this is the first instance I have known of in which there was really no reason to believe it caused any particular injury. It has been my experience that it occurs in every hatchery—that has been the case in all I have visited—if you look long enough for it. Of course it is not always abundant, but if you spend time there and look for parasites on the fish, sooner or later you are bound to find it.

DR. BANGHAM: In the case to which I refer, it did cause considerable damage. This was one of the new hatcheries that was leaking pretty badly, but as soon as we got the water running through with sufficient force we got it killed off.

DR. EMBODY: I had the same feeling that Dr. Davis had. We found Cyclochaeta down at Hackettstown in the rainbow in such numbers that we could not help thinking that they were doing some harm. Another instance was at the Japanese goldfish hatchery down near South Branch, I think it was, in New Jersey, where both Cyclochaeta and Chylodom were operating in exceedingly great numbers. Chylodon is bad in itself, but when treated with acetic acid, we found that all the trouble was eliminated. I noticed you said that the Ancyrocephalus was killed with acetic acid. We have had no luck this year with acetic acid on Ancyrocephalus, and I am glad to hear that they can be dealt with in that way.

DR. BANGHAM: I have only tried it twice. I can say that the alum solution does not touch them at all.

PRESIDENT TITCOMB: I will talk to you for a minute or two about this hatchery, and then you may stroll around while the luncheon is being prepared, after which we will discuss foods.

Connecticut is not an easy place in which to find a hatchery location. The larger water supplies are taken for domestic purposes. When I came here five years ago, or a little over, I circularized the state with specifications of what I wanted for water, and went into it in quite some detail. This circular was distributed among the sportsmen's organizations, wardens and others who might know about spring water supplies. I

visited a great many places where they had about enough water to raise a dozen or twenty trout—even after reading my specifications that is what they presented. It took two years to find this place here. I was brought within two miles of it a month after I came to the State of Connecticut, and was told there was nothing here, and turned back. Later on, one of the wardens told me about these springs up here.

This water rises almost entirely in the pasture above us. The stream which flowed here still flows, not quite in such volume, because we found that the water was made up of a series of small springs, and in attempting to bring these springs together by the use of land tile on the farm drainage system it was discovered we could only drain the ditch that we excavated, and the water was coming up all around it. Then we tried the drive-well system so prevalent on Cape Cod. The first well we drove down twelve feet gave us a yield of thirty gallons per minute through a two inch pipe—and we used the open points here. The second well, driven within two feet of the first, gave us an aggregate flow of fifty gallons per minute. We have now a lot of wells here, which is the source of supply for the hatchery; no other water is used inside the hatchery. That water comes out of the ground at about fifty degrees. We supplement that water outside the hatchery with the brook water, but you can use these wells if you wish. The driving was inexpensive when we did not strike rocks, but we struck rocks and had to pull up the pipes sometimes several times before we could get down through to the hardpan. The hatchery building was an old dance hall which became obsolete when the automobile came into play, and we moved it up here, taking it down for the purpose of doing so, and that gave us a nice, large building without any posts in it. The troughs in the hatchery are all connected directly with the sewer, but they can be turned into the outside troughs which, in turn, are connected directly with the sewer, or can be turned into the supply for the pools. The pools in series are connected with the sewer, so when we do any extensive cleaning, the water is carried to a settling basin down the lower part of the field. Dr. Belding spoke about that feature; it is more complete in a larger series of ponds which we are building over at the other side of this hill. After living here four years we discovered we had another place just as good as this right across here, adjoining our property on another stream, with apparently the same possibilities for driving wells. We are now using the spring water supply, and we control the water shed of both these water systems —we have about 600 acres. These pools up along here were the original brook bed. Instead of excavating pools we excavated a ditch down through here to carry the main water supply and the flood water. This ditch down through here is full of trout of various sizes. They occupy the stream all the way down through, and there is nothing to interfere with their going to the ocean; they prefer, however, to stay up here. We

do not allow fishing in this brook; that is why we have these wardens here today—to see that you do not get in there.

Now, the trout are all hatched in the building. Of course at this elevation here in Connecticut we have quite some winter, quite some snow. The water being 50 degrees in the winter, the fish are brought out in January and we begin feeding the middle of February, saving a lot of time in feeding and in hatching them in colder water. As they grow we have to spread them out, and in order to take care of them in the inclement weather of early spring we fill the troughs this side of the hatchery out of doors, and the entire production is carried in the outside and inside troughs until they have developed to the point where they begin to have to be thinned; then they are scattered in these pools. These pools, you notice, are very shallow, quite simple and inexpensive in construction. We prefer them in a great many ways to the more expensive concrete. They are easily cleaned; and Mr. Cobb has devised, by the way, a syphon system by which you can syphon out the debris that collects in the whirlpools in each pond, thus obviating the necessity of sweeping it down and subjecting all the fish to polluted water while the process is going on. If we were going to build all our pools over again we would build them with a connection at the outlet especially for the syphoning of this foul matter out of the pools. I have always disliked the system which prevails on the Cape, where the foul water and the impurities in the water have to be swept down through a long series of pools, subjecting all the trout to a very polluted situation for a considerable period every week.

These pools are cleaned every week. All the troughs are cleaned every day, and the sides of the troughs are scraped. We have had fin trouble here to some extent. Last year we used the copper sulphate as recommended by Dr. Davis, and this year we found we had the gyrodactylus, which, strange to say, became most pronounced in the upper of these pools, the pools below apparently being entirely free from it, although connected with the others so that the trout could run back and forth. After the attack they were very badly fungused, and then it began to work into the other pools and there were scattered cases in the hatchery. So that we had a tub of the treatment and the solution of acetic acid; we seined all the trout out of these pools and out of the troughs, netted them out, dipped them in the tub and cleaned the matter up, apparently. We have perhaps a few scattering fish now that have the trouble.

Of the two large pools below, the first contains yearling trout which we sorted from our distribution last spring—the smallest of our yearlings; they have now grown a good deal, but they were around five or six inches long when we distributed the larger ones for stocking purposes. The lower of the two pools contains yearling brown trout.

If you want to ask any questions before you look around I shall be glad to answer them. We will go up through the hatchery, and those who want to do so may inspect the water supply. Questions can be answered as we go along.

All these fingerlings you see here began feeding about the middle of February. There is one lot of smaller fingerlings in the hatchery which came from a very late shipment of eggs and which are less than half the size of these, which we call our normal production. We distribute the fingerlings at this size for all of our waters except our state leased streams. We are going to be forced very rapidly to distribute lawful length fish—that is, fish six inches or over; they are pushing for it since we began distributing these yearling trout to the state leased waters. In those waters we plant nothing but fish running from six to nine inches. The average length of our yearlings, in March or April is around seven or eight inches.

Mr. Radcliffe: What is the present capacity of the station here?

President Titcomb: We have some of our fish scattered in other places. Perhaps Mr. Cobb will answer that question.

Mr. Eben W. Cobb: We have about 500,000 fingerlings here. We have taken about 40,000 down to Farmington and 25,000 over to the other job.

President Titcomb: There are about 425,000 fish here now of the fingerlings, and then these two ponds of yearlings; 5,000 brown trout in the lower pool and 7,000 in the upper pool of the yearlings. The pools we are constructing now over on the other side are all larger than our largest pool below. The water is so arranged that we can run it into a sewer connected with a settling basin, or run it directly back to the brook, or run it into the next pool. We can drain any of these larger ponds and have the others supplied with water while the draining is being done. After drying the pond down, all the filth goes to the settling basin.

# DEMONSTRATION OF THE OXYGEN TEST

BY WILLIAM R. COPELAND.

*Connecticut State Water Commission*

PRESIDENT TITCOMB: Many hatcheries, as you are aware, are supplied with water which is not properly oxygenated. Some of you may want to make oxygen tests. The trout themselves when crowded can exhaust the oxygen in the water. We test our water at the springs and down through the ponds occasionally through the co-operation of the State Water Commission. I am now going to introduce Mr. Copeland, of the State Water Commission, who will give you a demonstration of making an oxygen test in this pool.

MR. COPELAND: The principal object of making tests for dissolved oxygen in natural waters is to determine whether they contain enough "free oxygen" to support fish life.

River waters absorb oxygen from the air, but the amount of oxygen which any particular sample will absorb depends upon several factors. One of these is temperature. Oxygen is a gas, and, following Boyle's well known law concerning gases, oxygen will expand as temperature rises. Therefore river waters, warmed by the heat of the sun, contain less dissolved oxygen than the cold waters found in springs and mountain brooks.

Organic matter upon decay absorbs oxygen greedily, therefore, if more food in the shape of scraps of meat is thrown into a fish pond or brook than the fish eat up, the portion not eaten will start to decay and exhaust oxygen from the water.

On the other hand, when streams flow rapidly over rocky bottoms and down waterfalls, bubbles of air will be caught in the water. Under these conditions the river water may become supersaturated with dissolved oxygen.

The amount of oxygen contained by water can be determined readily by applying chemical tests. These depend upon the fact that when manganese sulphate is added to a natural water that has been made strongly alkaline with a mixture of caustic potash and potassium iodide, one molecule of oxygen will be set free for each molecule of dissolved oxygen which the water contains. By adding to a measured volume of water treated as above, a reagent made up of such a strength that each cubic centimeter is equivalent to a known volume of iodine we can calculate the number of molecules of oxygen which the natural water contains.

The procedure to be used in collecting and testing the waters may be described as follows:

Collect the sample of the natural water in a narrow necked glass stoppered bottle holding from 250 to 270 cubic centimeters. Great care must be exercised to avoid contaminating this water with any bubbles of air that might be caught in filling the bottle. In order to avoid absorption of such air the bottle should be filled by pouring the water from a dipper through a glass funnel to the bottom of which a rubber tube is attached reaching nearly to the bottom of the bottle. The funnel should be kept full so that no bubbles of entrained air can work into the bottle through the rubber tube. Continue to pour water into the funnel until a volume equal to at least 1,000 cubic centimeters has been run down through the tube. This will wash out any air which the bottle may have contained. Drawing out the rubber tubing carefully so as to leave the bottle full of water, insert the stopper, taking care that no bubble of air is caught beneath the stopper.

Be sure to note and make a careful record of the temperature of the water which was run into the bottle.

Having collected the sample as described above, remove the stopper and add, by means of glass pipettes that are long enough to reach two or three inches below the surface of the water, one cubic centimeter of manganous sulphate solution and three cubic centimeters of the alkaline potassium iodide. Replace the glass stopper immediately and shake the bottle rapidly to mix the chemicals through all parts of the liquor in the bottle.

Allow the bottle to stand until the brownish colored precipitate formed settles to the bottom. This usually takes about ten minutes. When the sediment has settled, take out the stopper and add two cubic centimeters of hydrochloric solution. Shake the bottle well, taking care that drops of the water do not spatter upon the hands or clothing because the acid is very corrosive.

Examine the bottle and note whether all of the precipitate has been dissolved. If not, add a little more acid and shake the bottle thoroughly again.

From the time that the manganese sulphate is added to the sample until the precipitate formed is dissolved by the acid every precaution should be taken to avoid exposing the water in the bottle to the air. But after the acid has dissolved the precipitate the sample may be kept for many hours without interfering with the accuracy of the determination.

If the water contained a considerable quantity of dissolved oxygen it will assume a dark brown color when the acid is

applied. This color is due to the iodine set free in the reaction which takes place with the dissolved oxygen. If the amount of iodine set free is large, the water will have a dark brown color. If the water contained only a small amount of oxygen, the color may be only a light brown. If the water does not contain any oxygen at all no brown color will be formed.

In order to determine how much iodine has been released transfer 200 cubic centimeters of the brown water from the bottle to a flask and run into the liquor fortieth normal sodium thiosulphate solution until the brownish color fades to a light straw. Then add a few drops of a solution of potato starch dissolved in water. The starch, combining with the iodine set free, will produce a dark blue color. Upon adding more of the thiosulphate the blue color will gradually disappear. When all of the blue color is gone the test is complete. Note carefully the whole number of cubic centimeters of sodium thiosulphate used. If 200 cubic centimeters of the sample of water, after acidification, was used in the titration, the number of cubic centimeters of thiosulphate will be equal to the number of parts of dissolved oxygen in 1,000,000 parts of the original water.

A description of the methods to be used in making up the chemical solutions referred to above can be found in "The Standard Methods of Water Analysis" published by the American Public Health Association.

Mr. Copeland was asked to explain how the water was taken out from the brook in the first place, and he explained the procedure as follows:

Notice this funnel, which has a long rubber tube attached to the lower end; the sample bottle holding 250 cubic centimeters; the one quart dipper, and the thermometer.

Draw the stopper out of the bottle and introduce the rubber tube so that its lower end reaches nearly to the bottom of the bottle. Fill the dipper with a sample from the stream and pour the water from the dipper slowly through the funnel and rubber tube, taking pains to keep the funnel full, until most of the water in the dipper has flowed down through the tube and overflowed from the mouth of the bottle. While pouring the remainder of the water into the funnel, lift the rubber tubing out, so as to leave the bottle full. Insert the glass stopper immediately, taking care to avoid catching any bubbles of air beneath the stopper. Collect a second dipperful of the water and determine the temperature with a thermometer.

The bottle now contains water from the brook charged with the amount of the dissolved oxygen which the brook contains normally.

The second step to be used in testing the water for dissolved oxygen should be carried out thus:

Withdraw the stopper and add measured volumes of the reagents, described in a preceding paragraph, and follow out the instructions with regard to shaking the sample thoroughly. Be careful to avoid contaminating the sample of water with air and make careful notes concerning the exact volume of the water used in the test and of the reagents added.

It is necessary to note the temperature of the water carefully and to apply a correction as described in published tables for changes of temperature. Knowing the temperature of the water and volume of sample and reagents used, the test just completed indicates that the sample drawn from this brook contained 77% of the amount of oxygen required to saturate the water at the temperature observed. The fact that the water did not contain 100% of the amount of oxygen required for saturation indicates that a part of the oxygen has been absorbed by organic matter contained in the brook, or used up by the trout.

Tests taken at the spring, from which the brook starts, and collected on a previous date, have shown that the spring water is saturated with dissolved oxygen. If we go down stream still further and draw a sample from one of the lower ponds, the water collected there will be found to hold even less oxygen than obtained in the sample just analyzed.

You will note that Mr. Titcomb has provided shade over parts of the ponds along the brook. This shade protects the water from the heat of the sun in the same way that bushes, or overhanging trees, protect the waters of streams in meadows and forests.

Should the amount of organic matter in the stream use up all of the oxygen, the fish would die.

Therefore, by applying this test to samples of water collected at different points, one can readily determine whether the natural water contains enough oxygen to support fish life during its progress from its source toward the mouth. It may be interesting to note in this connection that speckled trout require more oxygen than brown trout.

In order to be sure that the tests for dissolved oxygen are made accurately the standard solution should be made up at frequent intervals and kept away from dust and sunlight. All

of the bottles and other apparatus should be chemically clean. Pipettes and other measuring devices should be graduated accurately and the volumes of water tested, the reagents used, etc., noted with particular care.

### DETERMINATION OF FREE C O2 IN WATER

Waters drawn from deep wells and peat bogs or swamps often contain carbon dioxide gas in considerable amounts. Cases have been known where waters drawn from deep wells, the bottom of which lay in a sunken peat bog, killed trout when the bog water was added to the surface waters in a pond at a fish hatchery.

When such a situation develops it is important to test the ground water for free carbonic acid. This can be done by following the procedure outlined below. Having collected a sample of the well or spring water pour 100 cubic centimeters into a tall narrow glass cylinder, add ten drops of standard strength phenolphthalein indicator and then run in measured volumes of forty-fourth normal sodium hydroxide from a burette until a faint purple color appears. The free carbon dioxide is equal, in parts per million, to ten times the number of cublic centimeters of the reagent used.

Mr. Titcomb has asked to have a demonstration made of a field method for testing the hardness of natural waters.

Natural waters contain various mineral salts in solution. These may be divided into two principal groups. They comprise salts of lime and magnesium. The composition of the salts varies, but in general they consist either of carbonates and bicarbonates, or sulphates, chlorides and nitrates. As a matter of fact carbonates aad sulphates are generally found together, but in some waters the carbonates are present in larger proportions than the sulphates, and in other waters sulphates predominate. These salts result from the action of rain water upon the various rocks and minerals in the earth's crust. Rain water is usually charged with more or less carbonic acid which tends to dissolve the minerals and the actual composition of the spring or surface water resulting will depend, to a large degree, upon the nature of the elements in the earth's crust. For example; among the granite hills of central Connecticut, where the rocks consist for the most part of granite, the storm water dissolves very little mineral matter. The surface of the earth in many sections of the western country consists largely of clay, limestone, and other comparatively readily soluble minerals. Therefore, surface waters, spring waters

and well waters existing west of the Allegheny Mountains often contain very considerable quantities of lime and magnesium.

By way of illustration it may be interesting to note that the highland waters collected from the hills in central Connecticut do not contain, as a general thing, more than 25 to 50 parts per million of minerals in solution, whereas waters from similar sources obtained in western New York, Ohio, etc., often contain from 200 to 300 parts per million of mineral salts in solution.

The carbonates may be divided into the "normal" carbonates and bicarbonates. The latter are combined rather loosely with carbonic acid. Therefore, if such waters are boiled and the carbonic acid gas is driven off the bicarbonate of lime and magnesium are broken up with the result that the normal carbonate is precipitated in the form of a white powder.

It is a matter of everyday observation that when soap is used for washing more will be required where the water contains quantities of lime and magnesium than in rain water or waters from the granite hills.

When waters use a considerable quantity of soap they are described as "hard waters." Therefore the determination of hardness by the soap method roughly approximates the amount of calcium and magnesium in the water, though it actually measures the soap consuming power.

The reagent used in making this test consists of a white castile soap dissolved in wood alcohol. A description of the method for preparing this soap solution will be found in the "Standard Methods of Water Analysis," Sixth Edition, page 28. For easy reference, however, the following extract from the Standard Methods is given below:

### STOCK SOAP SOLUTION.

Dissolve 100 grams of shredded dry white castile soap in 1 liter of 80 per cent beverage alcohol and allow this solution to stand several days. Denatured alcohol cannot be used. Wood alcohol free from oil or other denaturant may be substituted for the grain alcohol in preparing the solution. For preparation of a small volume, dilute 500 cubic centimeters of grain alcohol with an equal volume of distilled water, add 12 grams of shredded dry white castile soap, shake until it is thoroughly dissolved, stopper the bottle and store in refrigerator 24 hours to allow any suspended matter to settle, siphon off the clear top liquor and dilute with 50 per cent grain alcohol. The

soap solution so prepared must be tested against a standard solution of calcium chloride. In view of the fact that laboratory equipment is necessary for preparing these reagents many observers prefer to buy the solutions already made up and standardized from some dealer in chemical supplies, such as Eimer & Amend of New York City.

In order to obtain equipment that is suitable for field work, observers should apply to the Wayne Water Softening Company, Fort Wayne, Indiana. This equipment consists of a metal container and the following pieces of apparatus; a graduated glass dropper, a small square glass bottle graduated to hold 25 cubic centimeters, a 2-ounce round glass bottle, and a bottle containing standard soap solution.

The method of procedure may be described as follows: Collect from the stream, brook, or well under observation, 25 cubic centimeters of the natural water. Fill the glass dropper with standard soap solution and squirt this solution into the 25 cubic centimeters bottle, one drop at a time. As 25 cubic centimeters of distilled water will combine with 2 drops of soap, the observer should be careful to deduct 2 drops from the total volume of soap employed.

Each drop of soap solution added after 2 have been run in corresponds to one grain of hardness in a gallon of water. By noting, therefore, the number of drops added, one can readily calculate how many grains per gallon of hardness the water contains.

After adding a drop of soap to the 25 cubic centimeters sample, shake it violently for a minute or two and note whether a lather forms. Not only must the lather develop, but it must be so permanent that it will persist on top of the water, after shaking, for a period of 5 minutes. If upon adding one drop of soap solution the lather formed tends to disappear, add a second drop, shaking as before, and continue this procedure until enough soap has been added to form a permanent lather, as described above. For example; if the water tested is soft the 25 cubic centimeters volume may require 3 drops of soap, but if the water is hard it may require many drops of soap. In some cases 8 or 10 drops must be added. For example; highland water in Connecticut would require only 1 or 2 drops, whereas the hard waters from the limestone regions of New York, Michigan and Ohio would require 10 to 12 drops. It should be noted, in passing, that the soap test measures the total hardness; that is to say, both temporary and permanent hardness. Where the waters contain considerable quantities of salts of magnesium the observer will undoubt-

edly notice that he can secure a fairly good lather, and by that I mean one that will last for perhaps 3 minutes, by the addition of 7 or 8 drops of soap, but he cannot obtain a permanent lather until he has added 4 or 5 drops more. The first point measures in a general way the hardness due to carbonates, or so-called temporary hardness, and the total number of drops, which must be added to make a permanent lather measures both the temporary and permanent hardness. Attention should be paid to making careful measurements of the water tested and volume of soap solution added. The bottles must be clean and should not contain any water excepting that taken from the sources under observation.

Not only will elements dissolved from the soil increase the hardness of water, but also acids and chemicals discharged as wastes into the streams by factories often make the water very hard. For example; the chemical solutions resulting from the pickling of metals like iron, copper, brass, etc., which often contain metal compounds and acids in solution; lime compounds used in tanning leather, and purifying sugar manufactured from beet or cane, and the like, add to the hardness of river waters; therefore if the observer has occasion to test water from a stream upon which cities and industrial establishments are located, he may readily find, by testing samples of the water drawn from the river, that it will increase in hardness as it passes from its source to its mouth.

One of the subjects which has created a great deal of interest throughout the country refers to the raising of brook trout and other fish in our natural streams. Where these fish are not fed artificially they must depend upon the various kinds of food materials that exist in the water normally.

Crustaceans form a considerable part in the food of trout and other fish in certain streams. These crustaceans belong to many species, and observers have noted that some of the crustaceans are much larger than others. For example, crustaceans found in most of the soft waters of Connecticut are very small, though often very numerous. On the other hand, crustaceans growing in some of the hard waters from the limestone region of the west are comparatively large and also numerous. Tests made for hardness upon samples of natural waters have shown that the crustaceans found in soft waters were smaller than the crustaceans found in hard waters.

As a result of this observation we may assume that observers using the soap method for testing the hardness of natural waters would be able to select streams, or portions of

streams, where the larger and more desirable forms of crustacean fish food can be cultivated.

*Discussion*

PRESIDENT TITCOMB: Have you any questions to ask of Mr. Copeland?

MR. TUCKER: Would you make the same test to determine the amount of oxygen in salt water?

MR. COPELAND: Just the same, only bear this in mind; that when you come to test the salt water you will find that water containing salt will absorb a different amount of oxygen from water that does not contain salt. In making the test the procedure is exactly the same, but you have to determine the specific gravity of the water so that you will know what correction factor to apply. But that has all been worked out and you can find it, I think, in standard chemical works on that subject.

MR. LAIRD: Dr. Moore and I would like to know what is the soap standard used in these tests.

MR. COPELAND: The strength of the soap solution is to be found in "Standard Methods of Water Analysis," of the American Public Health Association.

PRESIDENT TITCOMB: Are there any further questions? If not we will now meet in the tent to hear the results of food and nutrition experiments.

The meeting having reassembled:

PRESIDENT TITCOMB: We have been working up to the subject which is now to be presented. The question of foods is always an important one with the fish culturists. The doctors tell us that liver is going to be as high as beefsteak within the next few years because they are all recommending it for anaemia.

I am going to call first on Dr. McCay, of the National Research Council, under whose direction we have had ten basic food experiments on trout at this hatchery, the work being under the direct charge of Mr. Bing of Yale University, who has been here every day, Sundays not excepted; we have kept him away from church since the first of January. He will give you the results of the continuation of the experiments conducted last year, and which were described in our last report.

# THE EFFECT OF VARIATIONS IN VITAMINS, PROTEIN, FAT AND MINERAL MATTER IN THE DIET UPON THE GROWTH AND MORTALITY OF EASTERN BROOK TROUT*

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A review of the literature shows few experiments that have attempted to determine the fundamental nutritional requirements of the lower vertebrates. In this age of rapid progress we are prone to apply generalizations in physiology which rest upon experimental grounds that are quite inadequate. This is well illustrated in the case of vitamin supplements which are used in many trout hatcheries. Few attempts have been made to show that the lower vertebrates require any known accessory factors. Hoffman (1) has recently claimed that frogs suffer from avitaminosis. His statement is based upon the fact that tadpoles fed bread sickened and died. They lived much better when fed less bread and when they were kept in water that was changed more frequently. One wonders upon what grounds this could be termed "avitaminosis."

The current belief that fish require vitamin A rests largely upon the work of Richet (2), Laufberger (3) and Coward and Drummond (4). Richet plotted the growth curves of two groups of fish, each group containing three individuals, for a period of two hundred and five days. One group received cooked meat and the other the raw product. Those upon the raw meat increased from 100 to 208 grams while those upon the cooked product only increased from 100 to 165 grams. He then reversed the diets and found that those which had previously received the cooked diet attained their normal growth rate upon raw meat while the other group which had previously had the better growth record ceased growing and died, when changed to the cooked product.

Laufberger fed four diets to groups of Amiurus Nebulosus. One group in an aquarium under natural conditions with green plants and sand received raw meat. A second received a mixture of casein, starch, melted fat, artificial milk and salt mixture; a third group were fed diet two, supplemented with egg yolk and yeast; a fourth received meat extracted with alcohol and ether. Only the third and fourth groups showed a slight

*This work was financed by the State Board of Fisheries and Game of Connecticut and was performed in consultation and co-operation with John W. Titcomb and E. W. Cobb.

growth and died in four to five months. The second showed no growth; the first lived and grew normally. Neither the experiments of Richet or Laufberger yield evidence that fish require any of the known vitamins.

The experiments of Coward and Drummond from which they concluded that trout require vitamin A are more convincing but their best conclusions rest upon indirect evidence. By feeding rats with trout eggs and with young trout at various stages during the absorption of the egg sack and after the completion of this process they found a decline in the total amount of vitamin A as the egg sack was consumed. From this they inferred that the young trout require vitamin A for their growth. They also fed three groups of trout for a short period upon experimental diets. The first group received fresh liver and egg yolk, another cod muscle and a third group received no extra food. The group receiving the raw meat lived and grew while the others failed. They attributed the growth of the first group to vitamin A. The character of this feeding experiment can scarcely warrant such conclusions.

The experiments of Davis and James (5) have furnished the best direct evidence that carp and possibly trout require vitamins A, B, and C.

The protein requirements of trout have never been determined. Embody and Gordon (6) in comparing the compositions of natural and artificial feeds find that about half the naturally consumed feedstuffs are protein. Osborne and Mendel (7) in an extensive series of experiments have shown that rats can be stunted by lowering the protein requirement below a certain minimum. If this protein level is increased after a definite period rats can resume their power of growth. Such protein relationships are of special interest to the naturalist since vicissitudes of living must frequently levy such restrictions upon fish under primitive conditions.

The economic importance of the utilization of fat and carbohydrates in the rearing of trout has been stressed in our other report. Knauthe (8) has shown that carp possess the enzymes which we regard as essential for the digestion of the common classes of feedstuffs. He doubted the existence of pepsin but found a strong trypsin which digested fibrin quite readily. He believed this was the most important element in the digestion of proteins. In both the pancreatic juice and the intestinal mucosa he found a lipase which split fat in the usual manner. Its activity was increased by the presence of bile. He found an enzyme capable of splitting starch in both an extract from the mouth and one from the pancreas. From

his experiments one must conclude that carp have the same power of digesting the major classes of feedstuffs as the higher vertebrates. Knauthe conducted a very interesting series of experiments in vitro to determine the activities of the digestive juices of carp. He found the nitrogenous portions of meat products were about 90% digested. He also demonstrated that 80-90% of the cereal proteins, beans and sunflower seeds, are digested by these juices in these tests outside the body. Further evidence that fish can use fat in their diet was contributed by Konig (9). He fed a variety of diets to carp and found a variation in the quality of the fat depending upon the fat of its feed. This is similar to the experiments of Radziejewski, who was one of the earliest of the many workers who have shown that the fat deposited in an animal's body will vary in quality with the fat fed. In conclusion of this brief consideration of the enzymes we wish to call attention to the recent paper of Dobreff (10) who has shown that the shark possesses a pepsin which acts in the presence of the hydrochloric acid of its stomach, with a maximum activity at 40° C. From this meagre evidence we would conclude that fish can digest proteins, fats and carbohydrates.

All our experiments have been performed at the state hatchery in Burlington, Conn. The water supply of this hatchery is furnished from springs. The temperature remains quite constant. Each of our experimental diets has been studied with groups of eastern brook trout (*Salvelinus Fontinalis*). Each experimental group contained fifty fingerlings and was confined in an individual screened trough, twenty-eight inches long, fourteen inches wide and eight inches deep. Each small trough was provided with a separate intake and outlet of water. The depth of the water in each trough was six inches.

The following diets were employed in the first series of experiments:—

| No. 1 (Low Protein) | |
|---|---|
| Casein | 10 |
| Starch | 82 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

| No. 2 (Medium Prot.) | |
|---|---|
| Casein | 25 |
| Starch | 67 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

| No. 3 (Medium Prot.) | |
|---|---|
| Casein | 50 |
| Starch | 42 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

| No. 4 (High Prot.) | |
|---|---|
| Casein | 75 |
| Starch | 17 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

No. 5 (Milk)

| | |
|---|---|
| Dried skim milk | 98 |
| Cod liver oil | 2 |

No. 6 (Medium Fat)

| | |
|---|---|
| Casein | 18 |
| Starch | 53 |
| Lard | 23 |
| Salt mixture | 4 |
| Cod liver oil | 2 |

No. 7 (High Fat)

| | |
|---|---|
| Casein | 25 |
| Starch | 10 |
| Lard | 57 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

No. 8 (Salt Low)

| | |
|---|---|
| Casein | 50 |
| Starch | 48 |
| Cod liver oil | 2 |

No. 9 ("B" Deficient)

| | |
|---|---|
| Casein | 50 |
| Starch | 42 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

No. 10 ("A" & "D" Deficient)

| | |
|---|---|
| Casein | 50 |
| Starch | 44 |
| Salt mixture | 6 |

All the above diets except 5 and 9 were supplemented with one-half gram of yeast for each fifty fish per day. The yeast was a product of standard quality whose vitamin B content had been determined in the Yale Laboratories. The cod liver oil was a standard product of tested potency.

The salt mixture employed was that of Osborne and Mendel (11). This is a mineral mixture which contains the inorganic elements in the same ratios as they occur in the ash of milk. As far as we are aware this principle of modeling a salt mixture after the ash of milk was first employed by Von Hoesslin (12) although it may easily have been employed at an earlier date since he claims no originality for his preparation.

All diets containing starch were prepared by heating water to boiling, putting in the salts and casein and finally adding the starch which had previously been suspended in a small amount of cold water. The solution was stirred diligently and boiled until the starch had set to a stiff paste. This paste was dried in an air draft in a steam heated oven. After drying it was ground to a powder and preserved in jars with screw tops. These diets were fed by making them into a thick paste with water.

In evaluating the effectiveness of the diets we have employed two criteria, the rate of growth and the rate of death. These rates have been plotted in the form of graphs, number one and two. Time in units of weeks has been plotted upon the ordinate and both the growth curves and the number of

trout alive at weekly intervals have been placed upon the abscissa.

The weights given are the average weights per fingerling and were obtained by weighing the total lot of fish and dividing by the number weighed.

For the purpose of comparison each chart contains a reference curve which shows the growth rate we have obtained upon diets of raw liver and dried skimmed milk. This may be considered as representing the best growth obtainable upon a natural feed. At the end of twenty weeks when the trout upon ration 1 were dying rapidly we divided them into two groups and placed them in separate tanks. One of these groups was continued upon the previous purified ration with its low protein content while the other was changed to a ration of raw liver. This raw liver curve is labelled 1a in Chart 1.

We obtained a moderate initial growth upon all the purified rations except number one which contained only ten per cent of protein. The growth curve of the trout upon this low protein diet shows that they require more than ten per cent casein. This curve also shows that trout can be stunted in exactly the same manner as rats and that the power to grow is not lost with age. They were able to develop an excellent growth rate after being stunted for five months. This growth rate which is resumed tends to approach the optimum upon a liver diet. In the accompanying photograph we have shown three pairs of trout which were the same age but whose growth rates had been altered by dietary factors. The largest were selected from the best of those reared upon a ration of mixed raw meats, the medium sized ones were reared upon dried skimmed milk and cod liver oil, while the smallest are specimens from those fed ration number 1 and stunted because of too little protein. This photograph shows the fact that the disappearence of parr marks appears to be a function of growth rather than age since the stunted trout did not develop these marks although they were equal in age to the others that did. Furthermore since these stunted trout did not lose weight they must have consumed enough food to provide them with sufficient calories for their normal activities. Since we could not show it upon the graph we wish to state that at the time the trout upon ration one were divided into two groups, there were sixteen alive. The eight upon the liver continued to die during the change in ration but three survived and it is their growth curve which is given. The other eight that were kept upon diet number 1 all died in the course of the next four weeks.

All other groups upon the purified rations began to die at the end of eight weeks after they had shown a moderate growth. From those upon rations two to four we must conclude that the protein is not the effective agent in the ration after it is employed at a level of twenty-five per cent or more. All growths are practically equal. Since the trout upon rations two, three and four received a diet adequate in protein, carbohydrates, salt mixture and vitamins A, B and D, we must conclude that the ultimate failure to grow and death must be attributed to factors other than those which we have included in these rations.

In chart 1 we have recorded the data from diet 5 which was dried skimmed milk. This group showed a good growth. At the end of fifteen weeks each fingerling had increased its weight by five times that at the start of the experiment. At this time they ceased to grow and began to die. Since this diet is adeqaute in protein, mineral, carbohydrates, and vitamine A, B and D, we must conclude that it is also deficient in some element that is essential for life and growth. Apparently it contains much more of this element than the purified rations. This question will be more fully discussed in our second paper.

In rations six and seven which we designed for the purpose of testing the use of fats by growing trout we have found that the growth is exactly the same as for those upon the other purified rations which were low in fat. The mortality rate for number 6 was less than for any other groups except one and five. We are unable to offer any explanation for these differences unless there may have been some variations in the time of boiling the starch and drying the various rations. From the results with ration 1 we might be led to postulate some substance which is essential for life but consumed in growth. We offer this as a mere suggestion, however, to serve as a temporary hypothesis for the experiments which we now have under way.

Neither the growth curves nor the mortality rates would show that the group upon ration 8 suffered from the mineral deficiency. In appearance, however, these trout were much more listless than the other groups and were markedly abnormal. An ash analysis showed no difference in the ash content of their bodies and those of a control which had received salt mixture. We feel that we can draw no definite conclusions from this experiment regarding the possibilities of the use of dissolved salts from the water since the casein which we employed was not washed and had a considerable ash con-

tent. In the second place the experiments are of too short duration. The solution of the question of the use of dissolved salts by trout must await the time when we can maintain them for long periods upon snythetic rations which are satisfactory for growth. After such a stage of experimental work has been reached it will be relatively easy to solve this question employing a purified ration that is low in ash.

Experiments upon diets nine and ten show that vitamins A, B, and D are not the controlling factors in the growth and life of the fingerlings. The deficiency of these substances played no appreciable part in the course of these experiments. Both the growth and mortality curves were the same whether the rations were supplemented or not. These experiments cannot be interpreted to mean that fish do not require these factors because in the first place we have not worked with highly purified products in preparing our diets, in the second place we have not demonstrated that they are deficient by other biological tests and in the third place we have not worked in water that is filtered free from organic constituents. We do believe, however, that these experiments show that none of these accessory factors are the cause of our failures in the use of purified rations, and that little result can be expected by including in the usual hatchery diets these expensive supplements.

## SUMMARY

By the use of purified rations we have shown that trout can grow if more than ten per cent of complete protein is included in the ration.

Our experiments have further shown that there is some factor not included in the usual category of protein, carbohydrates, mineral matter and vitamins A, B, and D which is the major factor in the growth of trout.

A limited amount of this factor is contained in dried skimmed milk which will provide satisfactory growth for a few months but fingerlings continued upon such a ration will ultimately fail and die.

These experiments have shown no detrimental action of relatively large amounts of fat although this conclusion must be accepted with caution since other factors limited the experiments to a short period of three months.

These experiments would not lead one to believe that the addition of the vitamin supplements of yeast and cod liver oil is of any advantage in the feeding methods of most hatcheries which employ the usual rations of meats and cereal grains.

Fingerlings which have been stunted for a period of five months can resume an optimum growth rate if fed a ration that will permit. The disappearance of parr marks appears to be a function of growth rather than age.

Observations in the course of these experiments would lead one to believe that trout like the higher animals will suffer from mineral deficiencies. This is of special interest since most of the hatchery rations employed at the present time are deficient in calcium, or in common terms lime.

We wish to thank Prof. L. B. Mendel who first suggested we include skimmed milk in our rations and who permitted us to use the Yale Laboratory for preparing them. We also wish to thank Mr. F. C. Walcott as well as his commission and Mr. J. W. Titcomb and E. W. Cobb for their excellent cooperation.

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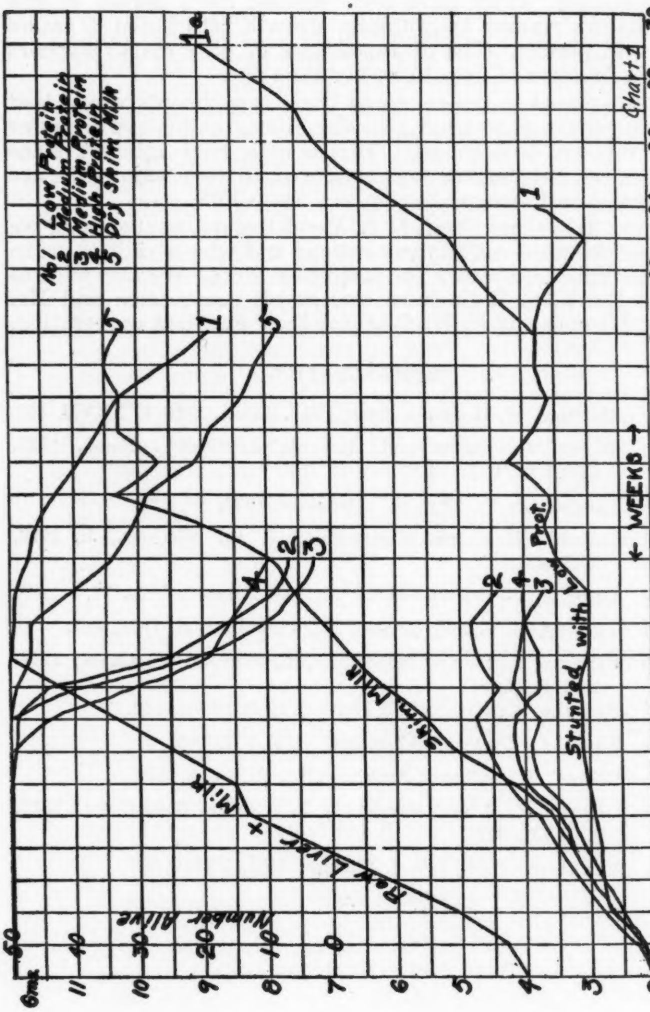
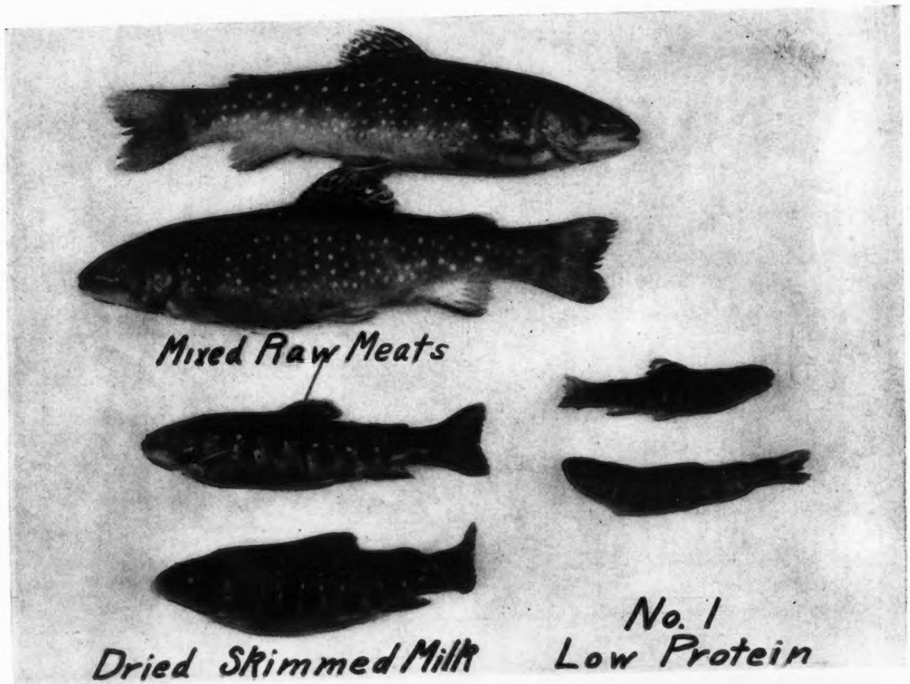
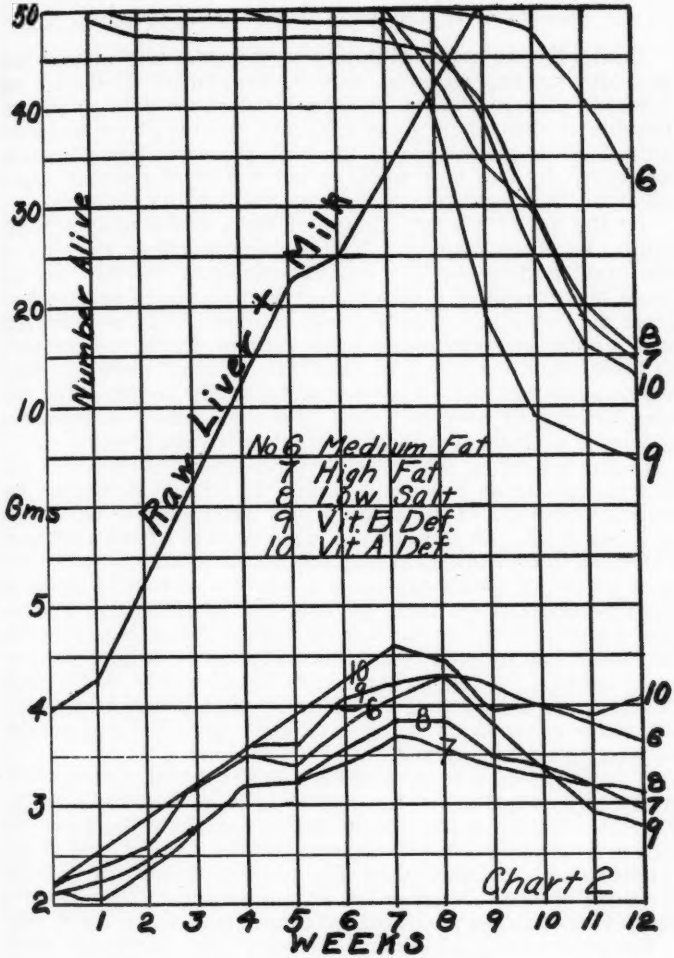



Upper curves show the mortality rates for groups. Lower curves show the average growth curves for individuals. Shows the effect of stunting for five months and the renewal of growth under favorable conditions.




Trout of the same age and from the same eggs but reared upon very different diets.




Curves showing the influence of fat levels and vitamin deficiencies upon the growth and mortality of brook trout.

# FACTOR H IN THE NUTRITION OF TROUT

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Lusk (1) has called attention to the extensive plans which preceded the experimental metabolism studies of Bidder and Schmidt. These workers originally determined to make comparable studies upon many different species of experimental animals. The magnitude of the task placed it beyond accomplishment by two lone workers but the ideal remains, and a study of their reports can leave no doubt of its value.

By the use of the rat, a mine of facts in the science of nutrition has been opened. At times one wonders, however, if the great enthusiasm for one experimental animal may not check the growth of a science, due to inability to develop laws from data obtained upon a single species. The fact that rats will mature and reproduce upon rations which are complete failures when employed in attempts to rear growing dogs, stresses the fact that there are undoubtedly undiscovered factors which will only be found when we make comparative studies of animals of widely different nutritional habits.

In our preceding paper we have reported the results of our experiments in an attempt to apply the biological method for testing feedstuffs to the study of the nutritional requirements of brook trout. In spite of the rapid growth of the science of nutrition, most workers recognize that no synthetic ration has been developed which can equal a mixture of natural foods in the promotion of optimum growth, reproduction and well-being in any animal. Most workers have called attention to this fact but it has recently been stressed in the reports of Osborne and Mendel (2) and Palmer and Kennedy (3). Maynard (4) has also shown that reproduction and lactation throughout many generations is never as good upon purified rations as upon natural feedstuffs.

In our preceding work we have found that the factor which is chiefly responsible for the growth of trout is not vitamin A, B or D. We have also found that trout show the same response to protein level as other animals, namely that it requires something more than ten per cent casein in the diet to secure growth. Protein fed at a level higher than twenty-five per cent shows no added influence upon the growth rate.

The experiments of Richet (5) which we previously cited, demonstrated clearly the fact that cooked meat is much less effective in promoting the growth of fish than raw meat. Cowgill employing dried liver, showed that the growth rate of rats

was accelerated. Maynard (7) found raw liver yielded a more rapid growth than the dried product. Morgulis (8) showed that trout digest cooked and raw meat equally well as far as the nitrogenous portions are concerned but that raw meat gives a much better gain in body weight. These studies are all confirmations under controlled conditions of one of the earliest discoveries in trout culture, namely that there is something in raw meat or milk which causes trout to grow and thrive and that this substance is deficient in cooked, dried products. The experiments of Wulzen (9) upon the nutrition of Planaria Maculata have added considerably to our knowledge of this thermolabile substance found in raw meats and milk. She found that "the power of liver and certain other foods to promote growth in planarian worms is reduced by exposure of these foods to heat. There was a noticeable decrease in the growth-promoting power of liver after an exposure to 100° for 1 minute to 56° for 10 minutes, to 45° for 30 minutes, to 37.5° for 24 hours." In lieu of a better term, until we have learned more of this unknown, thermolabile, growth substance, we will call it "factor H."

Inasmuch as Jephcott and Barcharch (10) found that milk dried by the spray process was marked by a deficiency in vitamin C, we have felt that this might be identical with factor H. The milk we previously employed had been dried by this method.

In the experiments upon which we wish to report in this paper we have been interested in the following subjects:—

The part played by mineral matter in the stunting of trout.

The use of dried meats in the rearing of trout.

The growth of trout upon a ration known to be satisfactory for growth and reproduction in the rat.

The need for roughage in fish rations.

The substitution of a "synthetic skimmed milk" for the natural dried product.

The minimum amount of raw meat that will satisfactorily supplement a dried skimmed milk ration.

The use of sugar in making up synthetic rations in place of starch.

The possibility that vitamin C is the cause of the failure of trout to grow upon snythetic rations.

Since many of these experiments are in progress at the present time, satisfactory answers cannot be given to all these questions but in many cases quite conclusive results have been obtained.

The composition of the rations that have been or are being fed are as follows:—

**No. 1**

| | |
|---|---|
| Casein | 10 |
| Starch | 82 |
| Salt mixture | 6 |
| Cod liver oil | 2 |

**No. 5**

| | |
|---|---|
| Dried skimmed milk | 98 |
| Cod liver oil | 2 |

**No. 11**

| | |
|---|---|
| Fresh liver | 61 |
| Dried skimmed milk | 37 |
| Cod liver oil | 2 |

**No. 12**

| | |
|---|---|
| Fresh liver | 90 |
| Dried skimmed milk | 7 |
| Cod liver oil | 2 |
| Starch | 1 |

**No. 13**

| | |
|---|---|
| Dried liver | 25 |
| Dried skimmed milk | 73 |
| Cod liver oil | 2 |

**No. 14**

| | |
|---|---|
| Dried liver | 68 |
| Dried skimmed milk | 25 |
| Starch | 5 |
| Cod liver oil | 2 |

**No. 15**

| | |
|---|---|
| Dried liver | 68 |
| Dried skimmed milk | 25 |
| Agar-Agar | 5 |
| Cod liver oil | 2 |

**No. 16**

| | |
|---|---|
| Ground wheat | 65 |
| Whole dried milk | 33 |
| Sodium chloride | 1 |
| Calcium carbonate | 1 |

**No. 17**

| | |
|---|---|
| Lactose | 50 |
| Casein | 39 |
| Salt mixture | 9 |
| Cod liver oil | 2 |

**No. 18**

| | |
|---|---|
| Casein | 10 |
| Starch | 85 |
| Salt mixture | 3 |
| Cod liver oil | 2 |

**No. 19**

| | |
|---|---|
| Cracks. | 53 |
| Lactose | 42 |
| Salt mixture | 3 |
| Cod liver oil | 2 |

**No. 20**

| | |
|---|---|
| Cracks. | 53 |
| Lactose | 37 |
| Fresh liver | 5 |
| Salt mixture | 3 |
| Cod liver oil | 2 |

**No. 21**

| | |
|---|---|
| Casein | 35 |
| Salt mixture | 3 |
| Lactose | 50 |
| Starch | 10 |
| Cod liver oil | 2 |

**No. 22**

| | |
|---|---|
| Casein | 35 |
| Salt mixture | 3 |
| Lactose | 50 |
| Starch | 10 |
| Cod liver oil | 2 |
| Orange juice | |

**No. 23**

| | |
|---|---|
| Dried skimmed milk | 93 |
| Fresh liver | 5 |
| Cod liver oil | 2 |

The same experimental technique that was described in the previous paper, was employed in these experiments. Each experimental group included fifty fingerlings and each group was confined in a separate trough with individual supplies of fresh spring water.

The rations were designed for the purpose of giving replies to the questions that have been listed. Since ration 1 of the previous experiments had produced stunting and contained a relatively high mineral content of six per cent, we have employed another, number 18, of exactly the same composition except that it included only half as much salt mixture.

In order to compare the relative effectiveness of fresh, raw liver and a cooked, dried product we have used rations 11, 12, 13 and 14. These contain about the same percentages of liver when calculated to a dry basis. Dried liver has been secured from two sources. The first was a product which the senior author (11) had previously used in blood regeneration studies; the second was a commercial product. By the use of the first preparation we were not only able to make comparative studies upon raw and fresh liver, but were also able to determine if the factor which is so potent in the improvement of blood formation were the same that is responsible for the promotion of growth in trout.

Since we thought that possibly the failure to grow was the result of a deficiency of roughage, we have included agar-agar in ration 15 and replaced it by an equal amount of starch in number 14 which serves as a control.

Sherman's stock ration, our number 16, has been widely used in many laboratories for rearing rats. It is known to give quite normal growth and reproduction. Since it is largely composed of ground whole wheat it contains ample vitamin E. We felt that the use of this ration would throw some light upon several factors in the diets of trout. This would show if a whole cereal grain contains the essential substance, factor H. It would cast some light upon the possible identity of vitamin E and factor H. It would determine if dried, whole milk contained the factor responsible for the growth of trout.

In order to determine whether the growth promoting power of dried skimmed milk was due to the relative rations of its lactose, protein and mineral matter or consisted of some unknown substance, we have made up "synthetic dried skimmed milk" from casein, lactose and salt mixture, present in the same rations as the naturally dried products. This mixture is number 17.

Since trout are known to thrive upon practically all raw meats we have tested another dried meat product, ground cracklings. These have been subjected to long periods of heating in rendering them free from lard. They are unusually satisfactory for an experiment of this nature since they retain sufficient fat to render feeding very easy. Furthermore trout eat them very readily. Dried cracklings have been employed in 19 and 20. In 20 was incorporated a small amount of fresh liver in order to compare its effect when present to the extent of five per cent in a dried meat ration and in dried skimmed milk. Number 23 was largely dried skimmed milk with this small per cent of raw liver.

Since no previous experiment had been designed to determine the identity of vitamin C and factor H, we have compared rations 21 and 22. These are synthetic diets of identical composition except that the latter was made up with orange juice.

The results of the experiments upon these rations have been incorporated in charts 3, 4 and 5. These have been plotted in the same manner as numbers 1 and 2 of the preceding article. These also show the average growth curves for the individual and the mortality rate for the whole group. The lower curves are the growth curves and the upper, the mortality ones.

Chart three shows the excellent growth obtained upon diets 11 and 12 which contained two different proportions of raw liver and skimmed milk. Although these experiments have been in progress for more than seventeen weeks there has been no death in either group. Diets 13, 14 and 15 afford striking contrasts. These contained practically the same amount of liver as numbers 11 and 12 respectively when they are both calculated to a water free basis for the purpose of comparison. All three groups showed some growth for a period of about 11 weeks. Growth then ceased and all began to die very rapidly. Of these three groups that one upon ration 13 which contained the most milk showed the best growth rate, indicating that the factor H which was present in the diets was in the milk and not in the dried meat. Since the dried liver used during about half of this experiment, had proved to be quite potent in blood regeneration (11), one must conclude that factor H is not the same. The blood regeneration factor seems to be somewhat resistant to heat while fatcor H is entirely destroyed.

For purposes of comparison, the curve of growth for a group fed upon raw liver is included. This demonstrates that the rate is somewhat less than for those reared upon milk and

meat combinations. The flattening of the curves during the last two recorded weeks is believed to have been due to the failure to eat which accompanied a change in the rate of water flow through the troughs. This altered flow was due to increasing the number of our experimental tanks, and drawing the water from the same source. Curves 14 and 15 were so nearly identical that we could show no difference with the scale employed. These curves not only show that roughage seems to play no part in the growths upon these rations, but also demonstrates that the experimental method employed is sound, since we were able to get identical growth curves from two different groups upon rations that were fundamentally the same.

Chart four shows that little growth was obtained with Shermans' stock ration for rats, number 16. There have been no deaths upon this ration thus far, however. This would seem to indicate that whole wheat and whole milk contain only a small amount of factor H. It also indicates that factor H and vitamin E are not the same substances. We hope to extend the study of cereal grains as trout feeds for practical purposes.

Curves 17 and 17-a represent the growths of individuals fed "snythetic dried skimmed milk," ration 17. Group 17-a was started eight weeks after 17. Neither group displayed the growth rate of those upon the natural product, as is found by comparisons with curves five of chart 1 and 4. Further evidence that "synthetic dried skimmed milk" is deficient in factor H is shown in the mortality rate for group 17. These started to die at an earlier period than any of the other experimental groups.

Curve 23 shows the remarkable influence of even a small amount of raw liver. Five per cent raw liver produces a considerably better growth rate when added to dried skimmed milk than is found upon dried skimmed milk alone. The mortality curves of chart 4 shows that there have been no deaths except upon ration 17.

Chart 5 includes the growth curves for groups fed rations 1 and 18. Thus far the stunting effect upon these low protein rations is identical in spite of their differences in mineral content. The similarity of these curves gives us additional confidence in our experimental technique. The curves upon rations 19 and 20 were identical. These not only show that trout cannot grow upon a ration of dried cooked meat supplemented by ample mineral matter, carbohydrates and vitamins but that an addition of a small amount of raw liver is

without influence. This would seem to indicate that the same amount of raw liver in ration 23 produces its effect from adding factor H to that already present in dried skimmed milk. On the other hand the growth promoting factor has been totally depleted in the dried cracklings and five per cent of raw liver is not enough to produce an influence. Since all these rations were adequately supplemented with yeast and cod liver oil they confirm the previous experiments which demonstrated that fatcor H is not vitamin A, B or D.

Chart 5 also contains the growth curves upon synthetic rations 21 and 22, to one of which, number 22, orange juice was added. Both were supplemented with cod liver oil and yeast. These are the same as those of charts 1 and 2 which show growth curves upon various other purified rations similarly constituted. Since the growth obtained upon ration 22 was identical with that upon diet 21, one must conclude that factor H and vitamin C are entirely different factors. These curves contribute further evidence that fatcor H is entirely different from vitamins A, B, C and D.

## SUMMARY


Our experiments indicate:—

(1) That trout are equally stunted upon rations containing ten per cent casein as the sole source of protein, whether these diets have three or six per cent mineral matter.

(2) That fresh raw meats contain a large amount of some unknown dietary factor which is essential for the growth of trout. We have termed this factor H.

(3) Factor H is thermolabile. It is totally destroyed in meats, which have been cooked and dried.

(4) Factor H is present in a limited amount in milk which has been dried by the spray process.

(5) Factor H is not identical with vitamins A, B, C, D or E.

(6) An amount of raw liver as small as five per cent of the ration, exerts a marked influence upon the growth produced by feeding dried skimmed milk. A similar addition to a dried meat ration is without influence.

(7) The use of lactose in making up purified rations in place of starch, shows no advantage for feeding trout.

(8) The use of agar-agar in fish rations yields no improvement in growth.

(9) "Synthetic dried skimmed milk" is deficient in factor H.

(10) The factor in liver responsible for blood regeneration is different from factor H since the former seems to be somewhat resistant to heat, while the latter is quite readily destroyed.

We wish to thank Prof. L. A. Maynard who has offered us much excellent advice in the course of the experiments. We also wish to express our appreciation of the many practical suggestions contribtued by Mr. Cobb and Mr. Titcomb.

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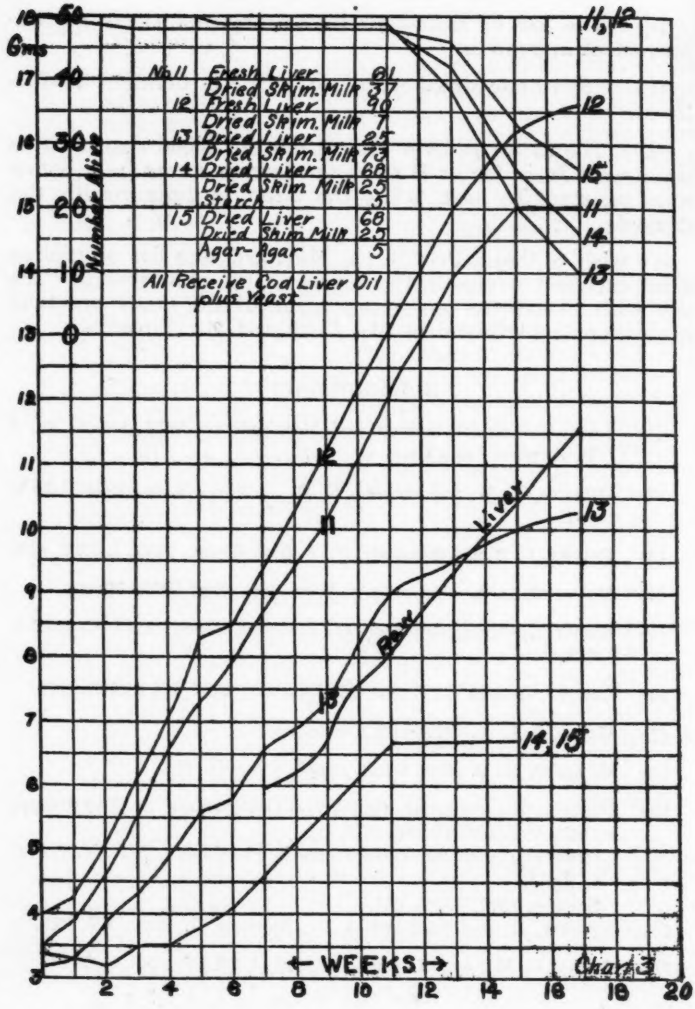
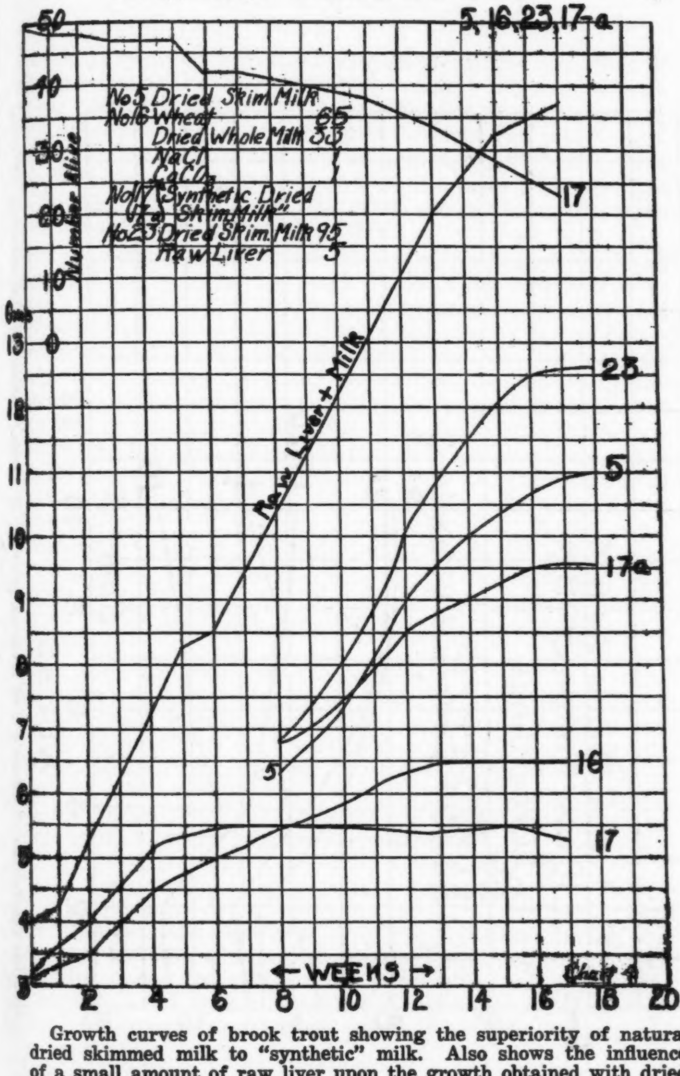
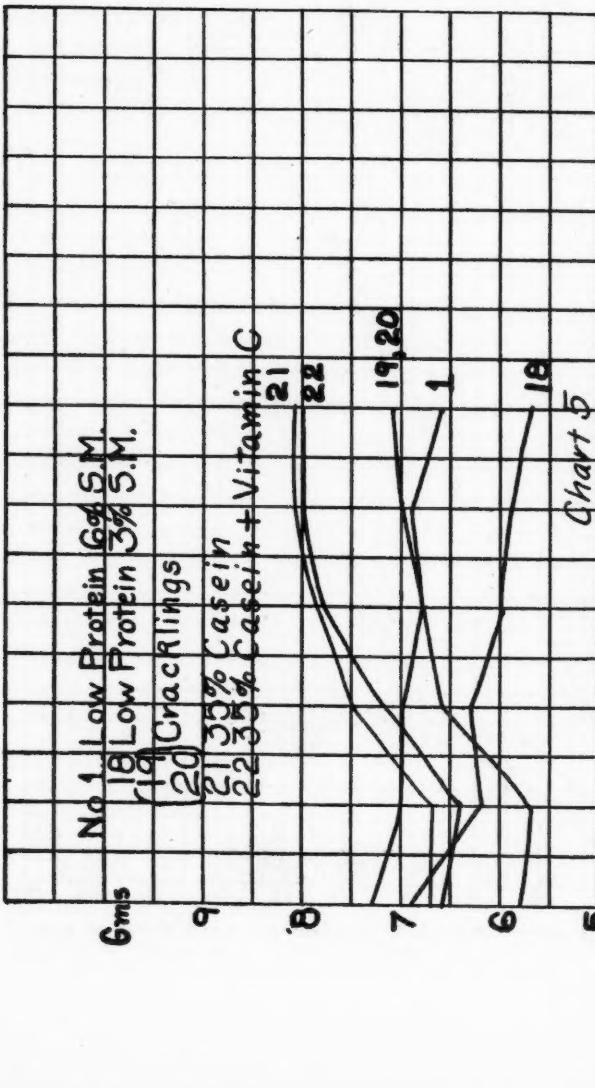



Curves showing the growth of brook trout upon diets of raw liver, raw liver and dried skimmed milk and dried liver and dried skimmed milk.




**Growth curves of brook trout showing the superiority of natural dried skimmed milk to "synthetic" milk. Also shows the influence of a small amount of raw liver upon the growth obtained with dried skimmed milk.**




Showing the failure of vitamin C to promote growth in trout. Showing the stunting of trout upon diets with ten per cent casein as the sole protein.

# GOALS IN NUTRITION

By Dr. C. M. McCay.

Nutrition in all its vicissitudes has had but one aim, that of producing strong, healthy, powerful bodies. We wish to nurture our cows well in order that they may bear powerful young and yield large volumes of good milk; we feed our pigs to produce the quality of pork that will command the highest prices; we wish to rear our game fish so that the most atrocious tale of a broken line must come true after the virtuous fisherman comes in contact with a virulent trout.

Economic competition which is but a way of stating and measuring the struggle for food, forces most animal life to attain a maximum growth upon the smallest amount and the cheapest or most plentiful food available. The revolution in the feeding of farm animals during the last two decades has shown the marked economies that may be effected by the application of the principles that have already been developed in the field of pure nutrition. One paragraph from the March report of the National City Bank may serve as an illustration: "The old ways of feeding requiring 11 or 12 bushels of corn to produce 100 pounds of hog, is giving way to a system based on new knowledge of the use of supplemental protein feeds and minerals enabling the feeder to produce 100 pounds hog live weight for seven bushels of corn or less. This system increases hog profits, of course, but lessens the requirements for corn and hence tends to lower corn prices and indirectly oats prices."

These sane economic considerations which apply to pigs apply to man and all his dependent animals. The incomes of few men would permit their entire maintenance upon meat, the most expensive of the foodstuffs, even if their wives tolerated such customs. Among the other divisions of animal husbandry, fish rearing may take its place as one of those which may hope for marked improvements and economies as a result of the modern advances in nutrition.

## THE CHEMICAL BASIS OF NUTRITION

Nutrition as a science was a fragile tree planted during the early years of the eighteen hundreds. For a century it was thoroughly cultivated by several generations of physicists, physiologists, and chemists with the generous assistance of quacks. Its present proportions certainly entitles it to a posi-

tion as one of the major sciences. But its roots must always be buried with the chemists and physiologists.

Everything that lives must have nitrogen. Both animal and plant life stores this in the form termed protein. In protein, nitrogen is combined in special form with carbon, hydrogen and oxygen. Protein is a major constituent of the blood, of the muscles and of the organs. Protein is the most expensive part of your foodstuffs and one of the substances you cannot omit from your dietary and live. Protein in its simplest form is familiar to everyone as egg white and as casein in cottage cheese from milk. We see it in meats where it is almost hopelessly entangled with salts, fats, carbohydrates in hundreds of combinations. For practical purposes you may assume that the raw liver which you feed your fish is one-fifth protein, the heart which you feed is about one-sixth and the dried skim milk which Mr. Bing is using in one set of his experiments is one-third. In conclusion we must emphasize again that without protein the animal cannot build up a body, and without protein no adult animal can maintain a body even after it is developed.

In addition to protein all animal life requires inorganic elements or that part of the diet which is usually termed the mineral constituents. These are not only invaluable for the formation of a skeleton but are also vitally concerned with the basic physiological functions of everything that breathes and lives.

After the requirements of the animal body have been met with proteins and minerals, there is still another major need, for fuel in order that the body may remain warm and have energy for movement. The animal world draws its fuel from those two great classes of foods which have been termed carbohydrates and fats and with which you are all familiar in the forms of starch and lard or sugar and butter.

In these brief paragraphs you have reviewed the life contributions of several hundred brilliant chemists and physiologists during the nineteenth century. Thousands of chemical analyses had shown the constitution of the foods upon which men and animals have lived, reproduced and died. But when the day came to combine these elements in nutrition, the fats, carbohydrates, proteins and minerals in order to rear and maintain healthy bodies, the chemists and physiologists seemed as far from their goal as the modern man does who attempts to create life from pure chemical compounds. Although we may not be able to create an animal at this day we may cer-

tainly assert that we can rear them upon purified diets with some degree of success.

In order to detect the real variations in an experiment we must always resolve it into its components. If a new gun and a new shell are submitted to the army they cannot shoot the new shell in a new gun, make a new record and conclude that the new gun is superior. No more can you expect to add cod liver oil to a diet of liver, get a good result and conclude that it is from the A factor when as a matter of fact you are feeding rich sources of vitamin A at the same time.

But before speaking of vitamins we must look briefly at the contributions of our age to the field of nutrition. We have made notable advances in two major directions, first that every adequate diet must contain certain unknown additions before an animal body can thrive; there are the notorious vitamins which have experienced a mushroom growth in importance during the past few years; second that all protein is not of equal value for the animal body and that some proteins are quite superior to others even when fed animals in the same quantities.

With this sketchy introduction to practical nutrition, we may consider the special aspects of the subject which may have a bearing upon the rearing of trout. Whenever an investigator attempts to dig to the basis of the nutritive requirements of a species, he must start by feeding that species the simplest foodstuffs that the instincts of the animal will permit it to eat. Hence the student reverts to the so-called purified diets which are the simplest mixtures of pure protein, carbohydrate, fat, mineral and vitamins which he can induce the species to consume. Such diets have been fed with excellent results to rats, mice, dogs, and birds. The criteria by which the success of the diet must be judged are: (1) the normal growth, appearance and development of the immature animal; (2) maintenance of the adult animal; (3) the reproductive powers of the mature animal, and (4) the length of life of the animal. Feeding such diets resulted in the development of the biological method of testing foods with its valuable train of discoveries which have but commenced.

In the rearing of trout you are not only concerned with turning out a product which can be reared cheaply and rapidly but you also wish to develop a product that is sufficiently hardy to readily adjust itself after it is freed in the stream. We know that food is the major factor in determining the character of the body of the animal that is produced. Another

example from agriculture may not be amiss. For many years farmers who fattened their pigs upon peanuts had been forced to accept a lower price for their product because hogs so fed laid down a soft fat. A fund was finally created by the meat packers for the specific purpose of studying this problem which on the surface would appear quite hopeless. Mr. Anderson of our division at New Haven attacked this problem using the rat, the best suited experimental animal for the nutrition worker because of its small size, short life, rapid growth and omnivorous food habits. After several years of very tedious work Mr. Anderson found that a rat fed peanut oil would grow and fatten in the same manner as the hog upon the same ration. Not only did he grow fat but he also laid down a fat which chemical analyses showed to be very similar to that of the hog. But the major problem was to harden this fat. Mr. Anderson found that this could be readily effected by merely starving the rat until he had consumed the soft fat for energy then fattening him upon some product which would yield the more valuable hard fat. These experiments have then shown the way to rear an animal upon a cheap food like peanuts and after the animal is reared convert him to a product that is of the greatest economical value. This has been introduced not to show the economies of nutrition but rather to illustrate the differences in bodies that may be produced by different diets.

In the experiments upon trout which we have been conducting at this hatchery we have been concerned with the following fundamental questions which are of equal interest to the practical man who is rearing fish and to the student of fundamentals of physiology:—

(a) The per cent protein a diet should contain to yield the most satisfactory growth of fish. The practical man may well ask if there is not an upper limit for protein. If the fish exceeds this limit he undoubtedly merely employs the excess for the production of energy. And he could probably derive this same energy from an equal amount of carbohydrate which is not only much cheaper but possibly better for the development of the body.

(b) Can a fish use cooked starch?

(c) Does the fish depend upon its food or water for its supply of minerals? Would there be any virtue in adding a mineral supplement to the usual hatchery diet?

(d) Can the fish synthesize the vitamins or must he have them added to his food from outside sources?

(e) Can a fish thrive upon diets that are high in fat if the other constituents of the diet are satisfactory?

(f) Can an advantage be gained by the addition of roughage to the diet of fish?

(g) Can a cheap, satisfactory dry food be developed from such products as dried liver, etc., which are now on the market?

These are but a few of the many problems which lie before the nutrition worker who is concerned with rearing fish. That this is of even greater interest to the scientific world as a whole may be more readily realized if you open a recent issue of the journal of the American Medical Association where you will find a recent editorial devoted to the question of whether or not the fish can synthesize the vitamins that are stored in the oil of his liver.

We may conclude this discussion with a few statements concerning the present status of liver as a food. During the past year the demand for liver for human consumption has enormously increased. This has been reflected in a corresponding increase in price. The men in the laboratories saw this change in liver price two years ago. Experiments at Harvard, Yale and Rochester in feeding liver to experimental animals, chiefly rats and dogs, had shown two marked virtues in this product, first that it makes a young animal grow at a rate far in excess of what was formerly considered normal. Rats will do this when only five or ten per cent of the diet is liver. In the second place the body that is deficient in blood, anemic, can form new blood upon a diet of liver much more rapidly than upon any other of the usual diets. This has resulted in a wide use in treating patients who have either suffered from severe losses of blood or who are anemic from some unknown cause. The growth promoting property has not been applied as yet but will probably ultimately come. A clever cartoonist, immediately after the publication of the discovery of this growth promoting property showed the eight-year-old son fed upon liver carrying his two-hundred-pound father around under his arm.

In conclusion I wish to say that such experiments as Mr. Bing will describe are only possible from the cooperative effort of two different types of experimenters, first the man who knows how to hatch and rear fish and has a good plant at his disposal and second the man who has devoted his entire efforts to chemistry, physiology and nutrition. Together we may look for real results where alone the progress of either must be quite slow. Thanks to Connecticut fisheries workers who have subscribed so heartily to the experiments Mr. Bing will describe.

# A PROGRESS REPORT UPON FEEDING EXPERIMENTS WITH BROOK TROUT FINGERLINGS AT THE CONNECTICUT STATE FISH HATCHERY, BURLINGTON, CONN.

By Franklin C. Bing.

*Yale University.*

## I. INTRODUCTION.

The rations used today in hatcheries for the rearing of trout consist very largely of liver, from sheep, cows, or hogs, and beef heart, sheep pluck and other meat products. The cost of these feeds is probably the greatest single item in the total cost of rearing fingerlings to the adult stage, and an effective substitute for these expensive foods is highly desirable from the economic standpoint. Many investigations of this problem have been undertaken in the past and reported in the Transactions of the American Fisheries Society. Some hatcheries have tried the rearing and feeding of insect larvae and other natural foods, with varying success. Other hatcheries have reported the substitution of vegetable foods such as beans for part of the meat rations. Some hatcheries report good results with cereal grain that is rolled into a flour mixed with water before feeding. The grain can be used either raw or cooked. Beans are usually cooked well before feeding, and several commerical hatcheries find that the cooking of all their food is beneficial. Cooking is known to break down starch granules into a paste that is more easily digested by the enzymes of the alimentary tract. Prolonged cooking also brings about an incipient hydroylsis of proteins such as collagen, and hence aids in their digestion. Bacteria are destroyed to a large extent by the heat of cooking; and on the other hand, much of vitamin A and all of vitamin C, are destroyed. Prolonged cooking of foods under steam pressure also destroys a great deal of vitamin B. It has been reported that the inclusion of cod liver oil in the food leads to the improved health and the better growth of fish. Cod liver oil contains vitamins A and D. Raw liver and other glandular meat products contain these same vitamins and also vitamins B and C.

At the Burlington Trout Hatchery of the Connecticut State Board of Fisheries and Game extensive investigations, begun in 1926 and still in progress, have been carried out on the nutrition of brook trout fingerlings. This present paper deals with some investigations of the growth promoting properties

of various commercial foods used in hatcheries. The work was was done under the supervision of Mr. John W. Titcomb and is an extension of the experiments reported by him in the Transactions for 1926. In the work described here an attempt has been made to answer experimentally the following questions: 1. Can vegetable feeds such as cooked beans be substituted for part of the meat rations? 2. Is the cooking of meat feeds of any advantage? 3. What effect has the addition of cod liver oil or other accessory food substances upon the rate of growth and the general bodily condition of young brook trout?

## II. RATIONS USED IN THE EXPERIMENTS.

Accordingly, the following rations were fed to nine separate lots of brook trout fingerlings:

1. Raw beef liver, only, was fed to the first lot.
2. Cooked beef liver, only, was fed to the second lot. The meat was cooked by steaming in a pressure cooker under about fifteen pounds pressure for one hour and a half. So treated, the liver lost about one-third of its wet weight and yet was soft enough to be readily taken by the fish. The fat of the liver was rendered out during the cooking process; it was of a light gray color and not greasy. In order to get a better comparison with the raw liver this was gathered up and mixed with the liver tissue as it was run through a grinder.
3. Raw beef liver, 75%, and cooked beans, 25%. The beans were a mixture of dried lima beans, soup beans, etc., and were prepared by soaking in water and steaming. The beans and raw meat were carefully mixed before feeding in order to produce as homogeneous a mixture as possible.
4. Cooked beef liver, 75%, and cooked beans, 25%. The two foods were mixed well before feeding.
5. Raw beef liver plus 2% cod liver oil. The oil was mixed with the food just before feeding.
6. Raw beef liver plus 5% cod liver meal. Cod liver meal was the residue left after extraction of the oil; the analysis furnished by the company supplying the material showed that it contained no vitamin A, but did contain iodine and vitamin D.
7. Cooked beef liver plus 2% cod liver oil.

8 and 9. These lots were fed with the food that was ordinarily fed to the fish at the Burlington Hatchery. It consisted of a mixture of raw beef liver, some beef heart, and a large amount of sheep pluck.

## III. METHOD OF CONDUCTING THE EXPERIMENTS.

The feeding experiments were carried out under actual hatchery conditions. Four wooden troughs, 12 feet long, 14 inches wide, with the water level at six inches—these being the type used inside the hatchery buildings—were set aside for each experiment. At the time of beginning these experiments 2,000 fingerling brook trout were counted into each trough, making a total of 8,000 fish for each experiment. These fingerlings were as nearly alike as it was possible to secure them. They all came from one lot of eggs purchased from a commercial hatchery the previous winter. Prior to the experiments they had been fed upon the ordinary feed of the hatchery, which at that period of the development of the fish, consisted mostly of raw beef liver. After one month's feeding of the experimental rations the number of fish was cut down to 1,500 per trough, or 6,000 per experiment, and continued at this number during the remainder of the summer.* One of the control lots, receiving ordinary hatchery food, was maintained at 8,000 fish in order to ascertain whether that number of fish were too many for the troughs to hold effectively. As shown in Table I, these fish in lot number 8 remained healthy and increased in weight as much as those that had been thinned down in lot 9, receiving the same kind of food.

Four feedings per day were the routine during the first four weeks of the experiments, the number of feedings being then reduced to three, and later to two, per day. Each lot of fish was weighed at the beginning of the experimental period and regularly thereafter at bi-weekly intervals. It should be noted that the amount of food given to the fish was all that they would eat. In order to insure that this was so, a slight amount of food in excess of that which was cleaned up in ten minutes was given at the last feeding of the day. The troughs were regularly cleaned and the excess feed removed about one-half hour after the last feeding each day. All of the raw feeds were mixed with a little water just before feeding so that the mixture would readily slip off a spoon, but excess water was avoided. In feeding the raw liver and beans ration the actual amount of liver fed was three-fourths as much as that given to the fish in trough one, receiving raw liver only. This was done in order that the 25% beans might actually serve as a liver substitute. The amount of cooked food fed to lot two was

*The number of fish per trough at the conclusion of the feeding experiment is rather more than most hatchery waters would permit in receptacales of the same dimensions and volume of flow. It is not to be interpreted as an indication of the number which can be safely carried at different hatcheries without proper test. —J. W. T

controlled in a similar manner by weighing out an amount equivalent to the weight of raw liver fed to lot one. This amount was fed slowly, allowing the particles to drop into the water so that the fish could seize them before they sank to the bottom. At first it was impossible to get the fish to eat much of the cooked food, and it was not for several weeks that they consumed an amount about equivalent to the raw food.

The water at the Burlington Hatchery was remarkably uniform in temperature, hydrogen ion concentration, and in dissolved oxygen content. Numerous determinations showed that the temperature of the water was close to 50° F. (about 10° C.) each day. The hydrogen ion concentration was fairly constant at pH 6.2, as determined colorimetrically. The dissolved oxygen was about 90% of saturation at the observed temperatures, and even after the water left the troughs, after having passed through all the fish therein, it was still well saturated with this gas. The water came directly from springs to the hatchery and had not passed through any fish ponds or troughs whatever before running into the experimental troughs.

## IV. RESULTS. GROWTH RECORDS.

The results of these experiments are given in the form of graphs showing the growth of the fish over a period of twelve weeks. (See chart.) The total weight of the fish in each experimental lot was divided by the number of fish, and the quotient, in grams, taken as the average weight per fish. For convenience, a table is also given of the weight of the fish at the beginning and end of the experimental period. (See table I).

As shown in the chart and table the best growth was obtained upon the raw feeds (numbers 1, 5, 6, 8 and 9). The fish that were fed raw liver plus cod liver meal (diet number 6) thrived best, weighing 2.49 grams each at the beginning, and 12.07 grams each, twelve weeks later. This represents an increase per fish of 9.58 grams; each fish more than quadrupled its weight in the twelve weeks period. The growth upon diets 1, 5, 8 and 9 compared favorably with that on diet 6. The fish receiving cod liver oil grew no better than their controls in lot 1, receiving raw liver only. The fish fed with the ordinary hatchery feed thrived somewhat better than those fed raw liver only. All these raw feeds were taken very readily by the fish.

The cooked feeds, on the other hand, were not eaten by the fish at first. After a day or two of feeding cooked feed the fish began eating a little of the new ration. But not for over

three weeks was it possible to induce the fish in troughs 2, 7 and 4 to eat an amount of feed comparable in amount to the raw food which they would have eaten. The flatness of the growth curves, 2, 7 and 4 at the start of the experiments brings out this fact. Thereafter the fish in these lots consumed more of the cooked feeds and showed a much better growth, not equalling the rate of growth upon raw foods however. At the conclusion of the experiments the fish in lot 2, fed cooked liver only, had increased in weight from 2.98 grams to 9.38 grams, a gain of 6.40 grams per fish. Their control lot, number 1, fed raw liver only, showed an increase per fish of 8.63 grams.

The fish receiving cooked beans in their rations did not produce as good growth as their controls receiving all meat. The fish fed upon cooked beans and raw liver, lot 3, did not grow as large as those in trough 1, that received raw liver only. The fish in lot 4, receiving cooked beans and cooked liver, showed the poorest growth of all. In all cases in which beans were fed with either cooked or raw liver, an effort was made to make a smooth mixture of the two, so that the fish would eat both foods, and not be able to pick apart one kind of food and leave the other. It was difficult to mix cooked beans with raw liver, but it was observed that the fish ate both foods.

### CONDITION OF THE FISH.

In any investigation of growth it is not only necessary to consider the increase in weight, but it is also essential to consider the physical character of the fish produced. Fingerlings are graded usually, according to their length. But it seems more satisfactory to consider other factors also, as the breadth of the fish, the general symmetry of the body, and the apparent health. Various practical fish culturists who visited the hatchery during the course of the experiments expressed the opinion that all the fingerlings were in fine condition. The fish in troughs 5, 6, 8 and 9 were obviously the largest, but in all of the nine sets of troughs the young trout were vigorous and healthy. The fish in trough 4, fed cooked beans and cooked liver, were smaller than any of the fish on the other rations. However, if observed alone and without reference to the fish in any of the other lots, they did not appear to be in other than first rate condition. It is well known that trout fingerlings in nature do not grow as rapidly as the well fed fingerlings in hatchery troughs and ponds. The rate of growth is very probably dependent upon the kind and amount of food that is eaten.

MORTALITY.

In the mortality rate also, there was little difference in the behavior of the fish on the different diets. A daily record was kept of the number of fish that died in each trough. During the summer the fish were troubled with gyrodactyliasis, all lots showing a small percentage of infection, and were treated twice with dilute acetic acid baths. Otherwise, no extensive disease was noticed. The number of fish dead includes deaths from all causes, accidental due to handling, and natural; it includes also the fish that died as a result of jumping out of the troughs, these fish being mainly in troughs 5 and 6.

V. CONCLUSIONS.

From these experiments with growing brook trout the following conclusions were drawn.

1. Cooking is detrimental to liver as a fish food. Fish that have been fed upon raw food do not take cooked food readily, and the change from raw to cooked food during the period of very rapid growth leads to a marked retardation in the growth rate. When the question of expense of materials and labor involved in cooking a large mass of meat is considered, there is additional argument against the adoption of cooked foods.

2. Beans do not produce growth equivalent to that produced by law river, although the possibility remains that they may be more economical.*

3. The addition of cod liver oil to raw or cooked liver rations is of no value so far as growth is concerned.

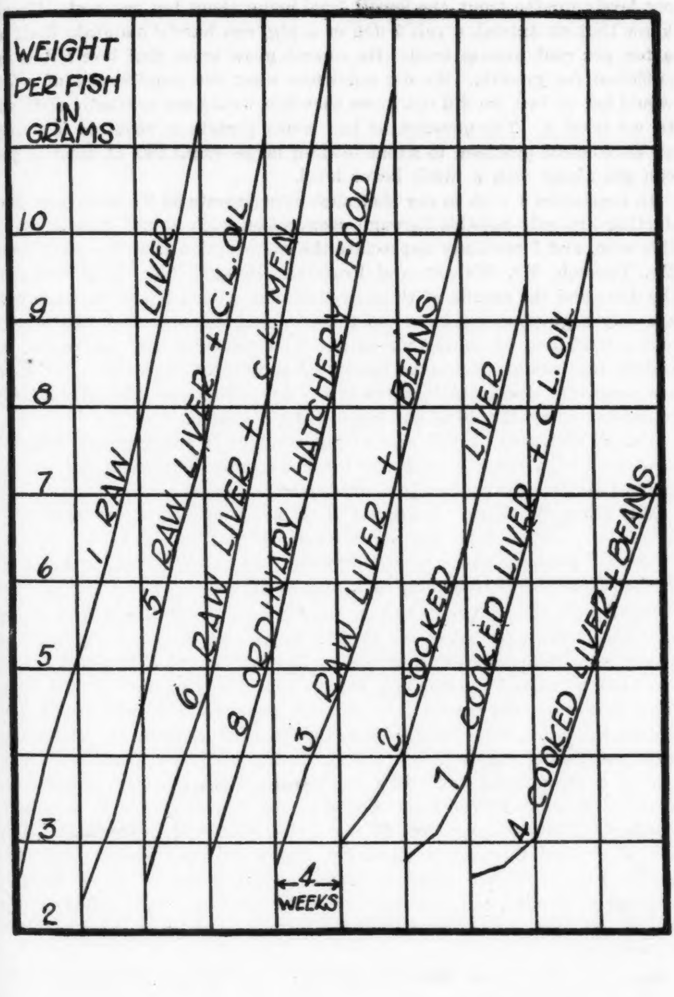
*In Colorado, Mr. Frantz has successfully used cooked food in raising trout on a commercial scale, followed by a mixture of steamed liver which is grated into the trough.

TABLE I. GROWTH RECORD.

| Trough | Wt. per fish at beginning. Grams. | Wt. per fish at end. Grams. | Wt. per 1000 fish, beginning. Ounces | Wt. per 1000 fish, at end. Ounces. |
|---|---|---|---|---|
| 1 | 2.60 | 11.23 | 91.6 | 396 |
| 2 | 2.98 | 9.38 | 105.1 | 331 |
| 3 | 2.68 | 10.11 | 94.5 | 357 |
| 4 | 2.62 | 7.11 | 92.5 | 251 |
| 5 | 2.34 | 11.14 | 82.5 | 393 |
| 6 | 2.49 | 12.07 | 87.8 | 425 |
| 7 | 2.80 | 9.86 | 98.9 | 348 |
| 8 | 2.81 | 11.72 | 99.2 | 413 |
| 9 | 2.84 | 11.46 | 100.0 | 404 |

TABLE II. MORTALITY RECORD.

| Trough | Food | Total mortality |
|---|---|---|
| 1 | Raw liver | 15 |
| 2 | Cooked liver | 35 |
| 3 | Raw liver and beans | 21 |
| 4 | Cooked liver and beans | 31 |
| 5 | Raw liver and C. L. oil | 48 |
| 6 | Raw liver and C. L. meal | 40 |
| 7 | Cooked liver and C. L. oil | 22 |
| 8 | Ordinary hatchery food | 18 |
| 9 | Ordinary hatchery food | 37 |


WEIGHT PER FISH IN GRAMS
10
9
8
7
6
5
3
2
1 RAW LIVER
5 RAW LIVER + C.L. OIL
6 RAW LIVER + C.L. MEAL
8 ORDINARY HATCHERY FOOD
3 RAW LIVER + BEANS
2 COOKED LIVER
7 COOKED LIVER + C.L. OIL
4 COOKED LIVER + BEANS
4 WEEKS

### *Discussion*

DR. MCCAY: We first set up our experiments with proteins at different levels for the trout, the lowest level being about ten per cent. We all know that an animal, a rat, a dog or a pig, can barely maintain itself at a ten per cent protein level. He cannot grow upon that level; it is insufficient for growth. We did not know what the requirement of a fish would be; in fact we did not know that fish would eat synthetic diets until we tried it. The question of how much protein is required is purely an economical problem, to avoid feeding large quantities of meat if you can get along with a much lower level.

In conclusion I wish to say that such experiments as we have been conducting are only possible through cooperation such as has been given in this case, and I certainly appreciate the co-operation that has come from Mr. Titcomb, Mr. Walcott and Professor Mendell. Mr Bing will give the diets and the results of these experiments which, I wish to warn you, are only beginning; we have had them in progress now only two months and a half, and of course we do not wish to draw any too radical or violent conclusions from experiments of such short duration. But there are some very decided differences in the fish which you will later be able to observe after Mr. Bing has presented his graphs.

MR. F. C. BING: I will confine my remarks to these graphs which I have conducted recently and which tell us something about the experiments that Dr. McCay has just mentioned.

MR. EBEN W. COBB: I suggest that Mr. Bing might say something about the use of cod liver meal which, I may say, was a new one to me. I presume there is a difference between the meal and the oil in the matter of convenience, cost, and so forth.

MR. BING: Mr. Titcomb had on hand a twenty-five pound sack of cod liver meal which he asked me to feed to one lot of fish. The meal is a very light, fluffy material; it is a residue of the cod liver after the oil has been extracted. According to the analysis furnished by the company that sells this material, it contains practically no vitamin A, but it does contain a thereapeutic dose, they say, of vitamin D. It has nitrogen and other material in it; it is usually used as a fertilizer. It is a nice, solid material and mixes quite readily wth raw food; moreover, It is easily taken by the fish. Cod liver oil is pretty hard to mix with the food; it tends to float off on the water when fed to the fish. The cost of the cod liver oil is about two and a half per gallon, while for the cod liver meal it is about fourteen cents a pound. We fed five per cent cod liver meal and two per cent cod liver oil to these different lots of fish. It seems that the cod liver meal would be much cheaper than the cod liver oil.

PRESIDENT TITCOMB: But as far as you have gone you think that the cod liver meal is just as good?

Mr. Bing: So far the two lots of fish show about the same vitality, the same vigor, and are thriving pretty well. With the experiments in their present stage, I would say yes.

Mr. Ashbrook: I would like to ask how the experimental rations compare with the basic ration that you have been using? What has been the basic ration in use at the hatchery?

President Titcomb: A mixture of liver and lights and hearts, and some sheep's plucks.

Mr. Ashbrook: Do you find that these new rations are better than the basic ration?

Mr. Bing: The rate of growth is shown here on the ordinary foods as given to all hatchery fish. They are equal to the average upon the raw liver alone or the raw liver plus the cod oil or cod liver meal. We have been limiting the food to just one meat in order to get the same basis for our calculations.

Dr. Embody: The whole milk—was that dried whole milk?

Mr. Bing: No, it was dried skim milk.

Dr. Embody: How did you mix that?

Mr. Bing: I mix the milk with a little water first—it comes in powdered form—then stir it around and get a kind of paste, and then add the cod liver oil to that.

Dr. Embody: You add nothing as a binder?

Mr. Bing: No, it sticks together pretty well. When it dries out it gets about as hard as a piece of chalk. You have to have just the right amount of water in it to keep it pasty.

Dr. Embody: I understand that when you feed about fifty per cent protein level you produce the best results?

Mr. Bing: Well, about twenty-five per cent protein level seems to be the requirement of the fish, so far as our experiments show. That is, they will grow at about what seems to be a normal rate on a twenty-five per cent protein level.

Mr. Buller: The milk food to which you refer is an evaporated milk?

Mr. Bings Yes.

Mr. Buller: Do you feed it in the evaporated form, or do you mix it and create a milk curd?

Mr. Bing: Create a kind of curd, yes.

President Titcomb: He does not sour it as you do, Mr. Buller.

Mr. Buller: Is your method better than mine? Do we take any of the vitamins out by creating the curd?

Mr. Bing: You feed sour milk, do you not?

Mr. Buller: Yes.

Mr. Bing: The difference between sour milk and evaporated skimmed milk is this: the latter contains all the salts that the sour milk would

lose; it has all the minerals in it that are in the natural milk, and in the proper portions for the young fish to grow on. In the sour milk you feed the curd and lose the whey or the salts in the water.

MR. BULLER: I am glad to find that out, because for many years we have been feeding milk curd, and we like it very much. If I can use that milk to better advantage than I am now, I want to know.

DR. MCCAY: We originally did not set up this milk experiment as a practical one. We have already found that young animals will grow and thrive and reproduce on whole milk, and we experimented with this not as a practical diet but merely as a starting point, and then tried skimmed milk where the food is about one-third protein and about eight per cent mineral matter and about fifty per cent carbohydrates. This dried milk costs about ten cents a pound, which is considerably cheaper than any meat you can buy if you convert this meat to a dry basis. We are using this as a starting point for theoretical feeding, hoping ultimately to get a mixture where we can combine this milk with meat and some of the faster growing substances and get a more ideal diet. We were not regarding it a complete, practical fish food in itself. The next experiment we set up will involve the trial of a milk and liver combination that will give us a rapid growth and at the same time a cheap carbohydrate, plenty of mineral and an adequate percentage of protein. As I say, in these first experiments we are not setting them up for practical feeds as a final proposition.

MR BULLER: We have been carrying on for quite a number of years the feeding of milk curd, and I am very glad to find out that it is a good thing if we can feed this in the evaporated form and get the salts which we are losing now—a good thing not only for fish but for human beings as well.

MR. RADCLIFFE: I would like to ask whether consideration has been given to the desirability of utilizing the whole fish, particularly sea fish. Recent developments in the field of dietetics have shown that land foods are lacking in elements which are present in abundance in sea foods. For example, sea foods have from fifty to three hundred times as much iodine as land foods. You can get practically all of the vitamins from sea food, and in the case of minerals, you can get the minerals from sea foods, which are rich in these. For Mr. Buller's information and to add to his probability of longevity, I may point out that the French have shown that the continuous eating of sea foods does away with the necessity for transplanting monkey glands, and things of that kind. I remember some experiments carried on for us some years ago at the Bureau of Animal Industry in which they fed hogs with various fish meals, shrimp bran, etc. We got for them a sample of shrimp bran which was low in proteins. They had a new manager at the plant where it was manufactured and he scorched it and did about everything he could to make it a poor product; yet the hogs fed with it did remarkably well. That led

me to believe that such foods as these contain desirable factors in sufficient quantities to make them a most desirable food, and I have often thought that the fish culturist might well give more attention to determining the value of these feeds for the feeding of fish.

MR. BORGER: I would like to ask, with reference to this last chart, what livers were used, whether it was beef liver or liver from sheeps plucks.

PRESIDENT TITCOMB: With the beans, you mean?

MR. BORGER: Yes.

PRESIDENT TITCOMB: That was beef liver. All the commercial fish breeders in Colorado, and there are numbers of them, raising great quantities, use steam cooked beans. With those beans they feed mostly the lungs rather than pure liver, and the lungs are also steam cooked. They begin feeding the fry on steam cooked liver, and continue that food until they are an inch and a half long.

MR. EBEN W. COBB: Someone asked about the basic food in the hatchery. There is another consideration that has to be taken in mind in that connection. All Mr. Bing's tests, except one, were carried on in the same manner, in order to show the comparative value of different foods. The two that received the hatchery food were given the regular hatchery care, and during a great part of the time have not had as many feeds per day as the other fish shown on the same chart, which of course would upset his experiment if it was simply an attempt to determine the value of the food itself. The idea was to show how these various foods he used compared with ours, taking ours just as all the fish got it.

MR. BING: The only thing I have tried to do in feeding these fish is to give them everything they would eat. I have perhaps been a little wasteful with some of your foods, Mr. Titcomb, particularly at the last part of the day when the troughs were clean, and immediately thereafter. I wanted to compare the growth resulting from these foods with as few other factors entering into it as possible. I wanted to make sure the fish got everything they would eat.

MR. BULLER: The experiments you are carrying on here are very valuable, because the cost of food is getting to be a very expensive item in connection with the artificial rearing of trout. Twenty-five or thirty years ago we were able to purchase sheep's plucks for about two and a half cents a pluck, the weight of the pluck being two and a half to three and a half pounds. To-day the cheapest we can buy is six and a half cents a pound, and at one of the hatcheries I am paying seven cents. Every year the cost is increasing, and it is going to be a serious item in the production of our trout at all the hatcheries. If we can find some method of feeding which will reduce that cost, it is going to be a very valuable thing indeed.

PRESIDENT TITCOMB: That is what Mr. Bing is here for.

Mr. Wheeler: In connection with what Dr. Radcliffe has suggested, as you know, I am in the oyster business; I am down on the water front and I shall be very glad, by way of experiment, to furnish either some opened oysters, which are high in nutritive values, or some mussels, which are high in iodine and other nutritive values, for your use, at your hatchery, if you care to take on that particular experiment.

President Titcomb: Thank you.

Mr. Adams: The commercial fisheries today, in marketing their products, are saving all their refuse matter at the shore or at the manufacturing plant. In other words, the filleting of the fish is making available enormous qauntities of heads and other parts of the fish which, if they could be worked into any part of the fish food, could be obtained for that purpose in amounts the like of which we have never seen before in this country. If any part of the salt water fish could be utilized to feed fresh water fish in hatcheries, by any process of manufacture, an enormous amount of material would be available for the purpose.

President Titcomb: That by-product ought to be made useful, but it means that those who dry it and prepare it have to exercise extreme care to keep it absolutely fresh—just the same care, in fact, that they use in handling the fillets which they ship to the market. There is nothing so bad as fish food which has stood around a little while. We are very strong believers in having our food absolutely fresh.

Mr. Graham: I understood Mr. Buller to say that he had been using milk curds for a number of years. Was that for fry?

Mr. Buller: After the fry are removed to the rearing pond we have men who do not do anything but feed all the time during the hours of daylight. Our feed to the fry in the buildings has been sheep's liver during the day, and then just before the men quit work at night there is a heavy feed of milk curd put into every trough and pond, which is taken up during the night by the fish. That has been the custom for years in our hatchery. In some of the hatcheries we use evaporated milk to make the curd, but where the hatcheries are in close proximity to milk skimming stations we buy the skimmed milk and create this curd. It is skimmed milk, remember; you can not sour whole milk. I think that is one of our safety valves against trouble with our fry.

Mr. Hayford: During the last two years, and especially this year, we have practically changed our whole system of feeding our young fish, and we have had the finest lot of fingerlings this year, and with the least mortality that we have ever had in the history of the hatchery. The first thing in the morning the feed is thick sour milk; the second feed is beef livers; the third feed beef livers; the fourth feed thick sour milk; and the last feed at night beef liver again; and every other day we have mixed in with this food four per cent crude cod liver oil. That

is red cod liver oil that we buy in thirty gallon barrels at a dollar a gallon. I think we have used something like one hundred gallons of it this year, and will probably use more next year. After you have fed this cod liver oil, the fish will not eat as much; I would say that the days we feed cod liver oil they will not consume as much food as they do the days we do not feed it. There must be some valuable food factor in that cod liver oil; it cuts down by perhaps twenty or twenty-five per cent the amount of liver you need to use, and at the same time the fish make more rapid growth and are freer from disease. If you have an opportunity next year I would like to see a check made of this combination with the other foods that are being experimented with.

PRESIDENT TITCOMB: I think I ought to have stated in reference to what we call the ordinary food at the hatchery, that we are using cod liver oil with the ordinary food. With reference to sea foods for the iodine content, I may say that we had among some adult trout which we carried through to the second year a tendency to thyroid tumor; therefore we have occasionally administered a few drops of iodine in the food.

Somebody inquired how often we fed. I will ask Mr. Cobb to answer that.

MR. EBEN W. COBB: We are down to two feeds a day on some of our fish. We have different sizes of fish. We begin feeding six times a day, pretty constant feeding, and then we work down until in the warm weather, when the fish are about as large as these you see in the pond, (3 to 4 inches) they get two feeds a day. We had quite a large consignment of eggs late in the season which are quite small fish. These are receiving the feed six times a day, the same as they would have at the same size if they had been with the others. But generally the feeding now is twice a day, and that will continue until the cold weather comes on, when we will drop to one feed a day.

PRESIDENT TITCOMB: Once a day for the large fish?

MR. EBEN W. COBB: Yes, during the cold weather, for the winter.

PRESIDENT TITCOMB: How are you feeling the yearlings now—once a day?

MR. EBEN W. COBB: Yes, once a day.

MR. LECOMPTE: I have been interested in this talk with regard to the compressed milk—I suppose it is a compressed cake?

DR. MCCAY: They remove the fat first, because that is valuable, and then evaporate it down. All they do is take the water out of the remainder of the milk, leaving in there all the mineral, the vitamin B, the carbohydrate and the protein.

MR. LECOMPTE: I was wondering if there would be more nutritive quality in that than there would be in clabber, which is of course sour milk.

DR. MCCAY: It depends on whether you are feeding the whole milk.

MR. LECOMPTE: It is just a question of letting the milk sour and feeding the clabber on a wooden plate in front of the pens.

DR. MCCAY: You have the cream in that?

MR. LECOMPTE: It is sour milk; it is not skimmed milk. I was wondering if this compressed cake could not be dissolved—I noticed that Mr. Bing said that when he diluted it a paste was formed. I was wondering if it would give an ingredient of the same nutritive value that the clabber would. It would be easier to handle and easier to secure. It is hard to get much clabber unless you have lots of cattle in the section nearby.

DR. MCCAY: In barrel lots the cheapest of this is eleven cents a pound.

MR. LECOMPTE: Do you think this would give the same nutrient?

DR. MCCAY: I would not say; you would just have to try it. The calorie value would be lower, because you have the fat in your clabbered milk.

MR. BULLER: I do not think Mr. LeCompte quite understands that the evaporated milk comes in powdered form; it is just like a barrel of flour.

MR. LECOMPTE: That is what I am trying to get at. If that evaporated milk comes in cake form—

MR. BULLER: No, it comes in the form of flour.

PRESIDENT TITCOMB: You can make that with sweet milk and turn it into sour milk.

MR. LECOMPTE: Clabber is only water and milk.

MR. DEROCHER: How many times a day did Mr. Bing feed these test fish, in the basic tests?

MR. BING: About four times a day.

MR. WHEELER: It has occurred to me since hearing Dr. Copeland's talk on the subject of hard and soft water that inasmuch as lime seems to be conducive to the growth of crustacean in a stream, it might be advisable and practicable to introduce a certain percentage of lime in your synthetic feed for trout in order to bring about a fast growing condition.

DR. MCCAY: That has already been introduced in our mineral mixture. Our mineral contains calcium, phosphate, potassium, sodium, chlorine, magnesium, iodine. Calcium is the lime.

DR. H. S. DAVIS: In this brief paper I have only attempted to touch on a few of our more striking results in the experience of the last two or three years.

# SOME RESULTS OF FEEDING EXPERIMENTS WITH TROUT FINGERLINGS

By H. S. Davis

*U. S. Bureau of Fisheries.*

For some time the Bureau of Fisheries has been conducting a series of feeding experiments to determine, if possible, the most suitable and economical foods for trout. These experiments are the direct outgrowth of investigations on the diseases which affect trout in our hatcheries. It soon became evident that real progress in the control of the various ailments so destructive to trout when crowded together in troughs and ponds could not be effected unless the field of investigation was extended to include a thorough study of the artificial conditions which necessarily obtain in our hatcheries. It is safe to say that, with the exception of the water supply, no single factor is more important in determining the success or failure of a hatchery than the daily diet of the fish. If we are to have strong, healthy fish, they must be supplied with suitable food and it is no small problem to determine what food or combination of foods may be relied upon to give the best results under average conditions.

While, as you all know, a great variety of foods have been used for trout, it is not by accident that in most cases the basic food consists of the liver, hearts and lungs of domestic animals. Not only are these products relatively cheap but they are richer in the essential vitamins than other meats. In a few localities other foods, such as the cheaper grades of fish are available, but with these few exceptions, I believe that fresh liver, heart and lungs must continue to form the chief constituents of our trout foods. Unfortunately, these foods are by no means ideal and they are continually becoming more expensive and oftentimes difficult to obtain regularly in good condition. None of the so-called artificial foods are equal to natural foods in promoting a normal growth and freedom from disease, and in planning our experiments we have been greatly influenced by the hope of finding some product which when combined with the standard meat foods will yield results more closely approaching those obtained under natural conditions.

For various reasons, we have been unable to undertake any fundamental investigations in the nutrition of trout but have been obliged to confine our experiments to the practical aspects of trout feeding.

Although this is the fifth successive season during which we have been carrying on these feeding experiments, I feel a great reluctance in drawing any general conclusions regarding the results of our work. Too often, we have found that the results of today entirely upset the conclusions of yesterday, and that what we have come to consider established facts may tomorrow require extensive modifications as the result of further investigations.

It is becoming more and more evident that to be of practical value, all feeding experiments should be continued for several months at least, and should be repeated for two or more seasons. Of course, in cases where unfavorable results are obtained from the very beginning such long continued experiments may not be necessary but, in general, our experience has convinced us that experiments carried on for only a month or two are usually of little value.

Furthermore, we have learned that each species of trout must be considered as a more or less independent problem and that what may be true of one species does not necessarily apply to others. Probably, the most striking example of this is the conflicting results which we have obtained from the addition of cod liver oil and yeast to the food of brook and rainbow trout. In no instance have we failed to get beneficial results when oil and yeast were added to the diet of rainbow fingerlings, while in the case of brook trout fingerlings, the results have just as consistently failed to show any benefit from the addition of the vitamin-rich products. Possibly the explanation of these diverse results may lie in the fact that rainbow trout appear to be more susceptible to vitamin deficiency than the brooks, and that the ordinary meat foods contain sufficient vitamins for the needs of the latter.

Last year, we attempted a comparison of the three common foods—beef heart, beef liver, and sheep liver—when fed to brook trout fingerlings. The results indicated clearly the superiority of beef liver when trout are to be raised to a larger size than the fingerlings commonly used for stocking purposes. Early in the season beef hearts gave the best results but when the fish were held to the age of six months beef liver was found to be markedly superior and produced twice the growth and one-half the mortality of its nearest competitor, sheep liver. These experiments are being repeated during the present season and so far conform to the results of last year; the fish fed beef heart having made a more rapid growth with less mortality early in the summer,

while at the present time the liver lots are forging ahead with the beef liver lot well in the lead.

In this connection it should be pointed out that the results of our experiments to date with the three meat diets mentioned above indicate that the maximum growth with these foods can be obtained by feeding beef heart for the first six weeks or two months and then changing to beef liver. Whether the superior results obtained with beef liver warrant its use in spite of its greater cost is a question which we will not attempt to decide.

This season we are trying a mixture of equal parts of beef heart and beef liver. The experiment has not continued long enough to enable us to arrive at any definite conclusions, but the results to date, both as regards growth and mortality, have been very encouraging. It seems reasonable to assume that, in the long run, a mixture of several meat products will prove superior to one alone.

Probably the most promising diet with which we are experimenting at present is a mixture of liver or heart with clam meal. This meal is manufactured from the dried "meats" of fresh water mussels and is a by-product of the mussel shell industry. Since we have only been able to obtain a small quantity of the meal we have been obliged to limit the amount of this product in the diet to 25 per cent. Last year, steelhead fingerlings fed beef heart with clam meal over a period of 97 days showed a mortality of less than one-half and a growth one-fourth greater than the controls fed beef liver. During the present season brook trout fingerlings on a diet of beef liver with clam meal have shown a greater growth and lower mortality than any other of our experimental lots. The lots fed clam meal mixed with beef heart and with sheep liver have not as yet shown any marked difference in growth but the mortality has only been about one-third that of the controls. So encouraging has been our results with clam meal that we are preparing to manufacture it at the Fairport, Iowa, Biological Station.

Owing to the common practice of cooking the food, a comparison of cooked sheep liver with the raw liver as ordinarily fed was attempted with conflicting results, probably due to a number of complicating factors. With brook trout the superiority of raw liver became more marked as the experiment progressed and at the end of 103 days the total mortality among the fish fed cooked liver was four times as great as among those on a raw diet. With young rainbow trout over a slightly shorter period cooked liver showed a

superiority over the raw products both as regards mortality and growth. However, an outbreak of fin disease among the fish fed raw liver probably accounts for the greater mortality and may have influenced their growth. Inasmuch as many commercial growers have reported favorable results from the use of cooked food, we are planning further experiments along this line in the hope that we may be able to harmonize our conflicting results. It is not improbable that the chief difference between cooked and raw liver is the change in physical consistency, and probably digestibility, produced by cooking. As a result there is apparently less loss in feeding the cooked liver than in the case of the raw product.

Our experience with cereals of various kinds have led us to the conclusion that these products have no place in the diet of fingerling trout. We are not yet in a position to express a definite opinion as to their value in the diet of older fish but are inclined to believe that it consists largely in preventing waste and providing "roughage" which, of course, forms a considerable percentage of the food under natural conditions.

With fingerlings, our results clearly indicate that the use of cereals in the diet is objectionable. Such rapidly growing fish need relatively large quantities of food which can be easily digested and assimilated. Not only are the starches undigested but when present in any considerable amount they must necessarily prevent the fish from obtaining sufficient quantities of protein and fat for optimum growth.

Some preliminary experiments last year with soy bean meal indicated that it might possibly be fed to fingerlings with satisfactory results. This meal is characterized by a high percentage of protein which more closely resembles animal protein in structure than other protein from vegetable sources. It would, therefore, appear to be an ideal cereal for use in trout foods but our results so far this season have failed to justify the hope that it might prove suitable for fingerlings. Used in combination with beef heart, beef liver and sheep liver, it has in all cases produced a much slower growth than that shown by the controls. Possibly it will yield better results when fed to larger fish.

Mexican beans, which have recently received considerable attention as a possible trout food, have proved even less desirable. When cooked and ground with heart and liver in the proportion of one part of beans to three parts of meat, they have produced, up to the present time, the slowest growth of any of our experimental lots.

Until this year, we have been obliged to confine our feeding experiments to fingerling trout. We are now carrying on several experiments with yearlings and hope in the near future to extend our work to brood fish. Any of you, who have attempted to conduct carefully controlled feeding experiments, do not need to be told that the space required for the work is very considerable and that the care of some 36 different experimental lots for several months is no light task. However, we are hopeful that increased facilities will enable us to materially increase the scope of our experimental work in the near future so that we can make more rapid progress in the investigation of one of the most important problems which confront the trout culturist.

I may add that before we can arrive at success in these feeding experiments, these fundamental experiments which have been undertaken here are absolutely essential. For various reasons the Bureau of Fisheries was unable to undertake experiments of that character.

### *Discussion*

MR. DINSMORE: Did I understand Dr. Davis to say that he considered beef liver more expensive than beef heart?

DR. DAVIS: It costs more by the pound. I was not referring particularly to beef heart; I was comparing the cost of beef liver and sheep liver.

MR. DINSMORE: I thought you said beef liver cost more than beef heart.

DR. DAVIS: No. I said that to get the maximum growth you would start the fish on beef hearts and then change to beef liver later. Whether the higher cost of beef liver would justify continuing them on it is a question. Perhaps my statement, though, was ambiguous. What I had in mind was the fact that we have determined that—and I think I brought this out in an earlier paper before this Society—you can get a better growth by feeding beef heart the first six or eight weeks and then shifting to liver. Beef liver will give you greater growth than sheep liver, and that is what I had in mind in referring to the cost—comparing the cost of beef and sheep liver rather than beef liver and beef heart.

PRESIDENT TITCOMB: Did you take into consideration, Dr. Davis, the waste you get from trimming the hearts?

DR. DAVIS: Yes, I realized that there was that waste. Beef hearts may be more expensive than sheep's liver, but what I had in mind was a comparison between beef liver and sheep liver, but not between beef hearts and beef liver.

PRESIDENT TITCOMB: If we can find that we can use at least a portion of cooked food, we can save all these trimmings; they are all cooked. All the material that would ordinarily be thrown away is cut up and fed to the fish.

MR. LAIRD: What is the comparison between feeding beef lungs and hearts or livers?

DR. DAVIS: That is a question which we have not taken up.

MR. LAIRD: I was wondering if there was any real value in lungs?

DR. DAVIS: Oh yes, there is no question about that. But we have no data on their relative value as food.

PRESIDENT TITCOMB: The most destructive vermin we have in our trout waters is the water snake. Mr. Viosca will now perform.

MR. VIOSCA: (Exhibiting water snake). This is the northern water snake, found in the coastal and mountain regions of northern United States. As you see, this fellow has swallowed eight trout. How many have you found in a water snake, Mr. Titcomb?

PRESIDENT TITCOMB: A water snake came down the flume and when he reached the end of the flume he climbed over into the last trough, apparently. This trough had been cleaned and thoroughly inspected within half an hour from the time the snake was found. I was up here at the time and saw the performance. The snake was stripped just as Mr. Viosca has stripped this one, and sixty-seven fingerling brown trout about an inch and a half long were removed. We had a snake out here which had three five inch trout in it, and another which had two six inch trout. Another one which was pursued but got crushed in the rocks without our getting him had a nine inch trout across in his mouth; he had not got it turned around so that he could swallow it, and that trout was allowed to escape and so far as we know is still living.

MR. VIOSCA: This snake has done his full duty, I think. There is one thing about the snake: if in nature you are not troubled with parasites to anything like the extent that you are in fish hatcheries, one of the reasons is that you have these predacious species. You can imagine a snake getting into a school of trout in the wild state; which ones will he get? He will get the ones that are diseased and parasitized. We have more snakes in Louisiana than there are in any other state in the Union, and I believe we have more fish in that state also than can be found in any other part of the country.

PRESIDENT TITCOMB: I want to explain our situation more fully, because this applies to some other snakes in this locality, and perhaps particularly in Rhode Island. We have very extreme drouths, usually in July or August. During these drouths our waters are low, the temperature gets high and the trout congregate in pools. If there are shelters, such as roots, in which these water snakes can park themselves, they will absolutely clean out the pool. I consider them more destruc-

tive on a stream where the waters are low than all the anglers we could put on them.

Mr. Viosca: Of course such conditions as these are entirely different from what I have been speaking of. I do believe these snakes should be kept under control where such conditions apply. But as things are in our state, as well as in some of the others, these snakes also have their natural enemies, they have their diseases and their parasites; when they cannot get as much food as they need they begin to get parasites and the parasites keep them under control, as well as their other natural enemies. For that matter, if they cannot get anything else they eat each other.

President Titcomb: We are going to have a demonstration of feeding these yearlings after the meeting concludes. In the meantime we can continue this symposium if anyone has any further remarks to make or questions to ask in addition to the matters which have been discussed.

Mr. Laird: I would like to hear more talk about the vermin. It is a matter of great importance.

President Titcomb: We have killed about thirty heron on these pools this summer. We trap the kingfishers with pole traps. We get quite a lot of them in the spring, and then after they go to the nest we do not see them until about this time of the year, when we get another lot of young ones.

A question was asked about the mink. We have some trouble with the mink, but I think we have caught only one or two in this particular area. We had an old mink down in some pools in Farmington which troubled us some. The common house rat is a pest when he gets into the trout pools—you will see a lot of holes right across on that bank which indicate their presence. The Biological Survey gave me a powder for the extermination of the rats; it is not destructive of poultry or dogs or warm blooded animals, but it does kill rats. This powder is administered with food. The first morning after we administered it we had seven or eight rats dead in that pool. From the look of things, it would seem that one or two of these fellows are still around, but that is the only place where we appear to be troubled with the house rat. The house rat will undoubtedly catch trout when it gets into this sort of parking place.

Mr. DeRocher: Do the heron bother you here?

President Titcomb: Early in the morning they follow the brook right up through the woods.

Mr. DeRocher: We have them come in at Nashua just about dusk, and they are there during the night. I was wondering whether they took the trout.

President Titcomb: I think they do.

Mr. DeRocher: That is my impression.

# ECONOMIC FACTORS IN THE SALT-WATER REARING OF SALMON

By Arthur S. Einarsen

*Assistant Superintendent of Hatcheries*
*State of Washington*

As time rolls by experience causes different conclusions to be drawn relative to the best practices in fish culture. This is true particularly in the case of the salmonid fishes.

When the first salmon hatcheries were operated, the handling of eggs was considered a very delicate operation. It was also considered necessary to strip the eggs rather than take them from the dead female by slitting the abdominal cavity, the present practice, which is more rapid and results in a better grade of eggs.

Innumerable examples of changed practices might be cited, all pointing to improvement in technique, but I shall concern myself chiefly with the subject of rearing salmon fry in brackish or salt water ponds, as it is a new development and comes as the direct result of a change in policy in most of our salmon hatcheries. At the inception of artificial propagation it was the approved method to hatch the eggs and release the delicate little fish almost at once. It was soon evident that the practice was not logical; as natural hatched fry were retained in the stream bed gravel far longer than this and it could be readily seen that fry in the sac stage were quite helpless and a choice morsel for all predatory life. At this point the practice changed somewhat and the fry were retained in the hatchery troughs until the yolk sac was absorbed and the fry swam up and were willing to take food. They were then released and allowed to forage for themselves. At most salmon hatcheries today this method is followed, not that it is entirely accepted as the best, but because it is the most economical under our present development.

During the past ten years considerable has been done in an organized way to develop a satisfactory rearing system for salmon, which has been deemed a pressing need due to the menaces which have sprung up on all our streams. Since a great amount of attention has been paid to the protection and propagation of the same fishes, particularly the trout and charrs, every hatchery stream has become infested with predatory fishes attracted by the hatchery waste and remaining there in ever increasing numbers due

to the protection which this area affords, as our state laws prohibit the taking of trout adjacent to a hatchery rack. The rearing system is the answer to this problem. To date the greatest handicap in artificial rearing is the lack of a satisfactory food supply for the growing salmon. When it is realized that the state of Washington feeds approximately 3500 lbs. daily for a five month period yearly, it is readily appreciated that the food supply must be cheap, easily kept and available in great quantities. It has been suggested from time to time by various agencies that beef lungs, or liver be used, but as their cost would result in the utilization of nearly one-half of our yearly appropriation. it would be impossible to continue the practice for any length of time. As a result of our studies we are using the only satisfactory food available from an economic standpoint. This is condemned canned salmon; the result of improper canning. We are able to procure sufficient to serve our needs at about one-tenth of the cost of other available foods and although it is not entirely satisfactory, it lends itself well to our needs as it is easily handled, can be accumulated and stored during the slack period at our hatcheries and can be held in suspension in the water making it more readily available for feeding fry.

Any unchanged diet is not entirely satisfactory and an addition of natural food is to be welcomed, but in the limited space of a rearing system the development of any great quantity of natural food is impossible. When the idea of rearing salmon fry in brackish or salt water ponds was suggested, it was taken up with interest as it is an accepted fact that sea water contains a much greater quantity of animal and plant life than fresh water, and should, therefore, approach that balance necessary for rearing fry satisfactorily when augmented with artificial food.

Some pioneering work had been done in this field by the Alaska Territorial Fisheries Commission and in November 1923 the State of Washington located their first salt water rearing pond on Hoods Canal at Whitney Spit. The pond is in reality a lagoon about seven acres in extent. At low water the area is reduced to five acres. Across the entrance to the lagoon a heavy piling frame or dam was constructed, 50% of which is solid construction and the other 50% has frames so fitted that screens can be slipped into them and the water containing minute plants and animals flows readily through it, furnishing the fry

with the choicest food and excluding all fishes over one-half an inch in length. Three sizes of screen are used, eight meshes to the inch being used when the fry are first released in the pond. As soon as the fish have developed enough not to pass through a larger screen the 6 meshes to the inch screens are used and finally the 4 meshes to the inch. The screens are brushed regularly to prevent clogging by the accumulation of sundried sea growths and by alternation we find that the galvanized screens will last two years.

The first few years of operation were rich in experience. Details of operation were worked out until at the present time the work progresses very smoothly. The pond operates on the following plan:

The fry to date have been hatched in an adjacent hatchery and held until the yolk sac has been absorbed. The fry are then placed in transfer cans and before being placed in the pond the fresh water is gradually displaced by sea water. This has a very stimulating effect and should not be too rapid as it is a considerable shock to immerse them in salt water suddenly. Fry that are approaching exhaustion in the transfer cans immediately regain their strength and normalcy upon being freed in salt water.

For the first two seasons the pond was operated the mixed fish that had accumulated in the pond during the summer season after the fingerlings had been released were seined out, but the results were not all that could be desired and in recent years the removal of the mixed fish by dynamiting has been found to be the most successful. The screens are placed in position about a month before the fry are due to arrive from the hatchery. The whole area is then thoroughly mined; using about 300 pounds of 40% rock dynamite. In a few days the dead fish begin to show up in considerable numbers and two weeks later another systematic mining causes those few fishes which escaped the first barrage to be completely wiped out. This is entirely necessary as experience has shown us that salmon fry are ideal food for any fish larger than the fry themselves and where they become the only source of bulk food, great inroads are made in their numbers. The last two weeks before the fry are released allows the pond to return to a normal condition as the tide fills and reduces the pond twice daily. Plancton tows reveal a great abundance of schizopods, copepods and diatoms.

For a few days after the fry are released in the enclosed area very little is done in the way of giving them artificial food. The reason being that hunger causes the tiny salmon to forage for themselves and they quite naturally prey on the available life in the pond. As this supply is limited for the number of fry in the enclosed area, which varies from one and one-half to three millions, it is necessary after a few days to augment this with artificial food. For this purpose condemned canned salmon is very practical as we can have it shipped to this isolated pond during the slack season, where it is then held in storage until needed. Any fresh food supply would be impossible to handle at this location as there are no daily transportation facilities.

The salmon is usually in 1 lb. tall cans. To prepare it for fish food several cases are opened by a very rapid method which we have developed and the whole contents placed in a cider press. The excess water is pressed out until the fish is just moist. It is then worked through a fine meshed screen resulting in a fish meal about as coarse as graham flour. The meal, in order to be ideal, must be fine enough for the tiny fry to be able to swallow it readily and it must have the water content so reduced that it will remain in suspension for a considerable period when thrown on the water, as salmon fry are not bottom feeders and heavy meal will sink quickly to the bottom where it is a total loss.

It is only necessary to feed in one area. The fry will learn to congregate there to satisfy their hunger. The most satisfactory place is near the screen dam as the inflowing tide sets up a current and diffuses the meal over a great area. Then too, it results in a mixed feed as the inflowing current carries an abundance of marine life which the fry feed on very diligently. As the tide floods twice daily for periods of about 2½ hours each the feeding periods should be regulated to conform to the tides.

Salmon fry are always in search of food and it is therefore necessary to feed them heavily. No ill effects result from over-feeding, but disaster will soon follow should under-feeding be practiced. It has two distinct disadvantages: 1st it causes cannibalism to develop, the tiny fish attacking each other's fins and finally the body and, 2nd, fry that become emaciated by under-feeding can never be brought back to normal flesh and continue as weaklings, eventually dying.

To illustrate their capacity for food our feeding records show that during the past season 1,500,000 pink or humpback salmon fry were started out with a feed on Jan. 10th of 50lbs. of salmon meal. This was gradually increased until in June when the fingerlings were released they were consuming 500 lbs. daily with an increase in size from 1 inch to an average length of 6 inches. This is truly remarkable growth for pinks as they rarely exceed 20 inches at maturity, more often averaging 15 inches.

The great care to produce a fine meal is not necessary when the fish reach a length of 3 inches. They are then able to feed from chunks made by compressing the cooked salmon.

The care of the stock in the pond is a matter of routine work once the fish are established there.

The actual cleaning necessary consists of brushing the screen dams twice daily. Little attention is paid to the waste on the pond bottom as the fungal growths develop very slowly and the polluted conditions that result from feeding wastes that occur in fresh water rearing do not obtain. The change of water which occurs at each flood tide aids this situation also.

Our greatest menace is hot weather. Athough an average summer temperature is about 70 degrees occasions occur when the thermometer registers 85 degrees. Should high temperatures occur during a period when the tides are at flood early in the morning and late in the evening, the pond is exposed during the middle of the day to the sun's action when its water content is at its lowest. Although there are areas in the pond of a depth of 15 feet the greater portion is only from 2 to 4 feet deep and the temperature will rise to a dangerous point, 70 degrees having been reached. This results in two changes: the oxygen content is reduced and the waste begins to deteriorate. We therefore, have found it more practical to arrange to release our fingerlings at the first critical period in the summer.

The fish are then well able to take care of themselves and should be equipped to live on the natural foods available, due to the opportunity to obtain natural food in the pond.

Experiments have been run with both chum (Oncorhynchus keta) and pink (Oncorhynchus gorbuscha) fry as their habit of dropping from the streams to brackish water

shortly after absorbing the yolk sac is well known and they are therefore the more logical to experiment with.

The chums attained the greatest size in the same length of time, but it has not been established definitely whether this was due to the conditions or a normally more rapid growth as the chum is in the adult stage on an average three times as heavy as the pink.

The economy in salt water pond operation lies in the limited hired help necessary to rear salmon fry; one man being able to care for twice the number in salt water that he would be able to in fresh water. The growth has been found by comparison to be three times as fast as in fresh water rearing ponds in the two species experimented with. The fingerlings are better fitted to take up their natural life in freedom and the menaces in the adjacent salt water are not nearly as great as will be found adjacent to the hatcheries where multitudes of predatory fishes congregate and hundreds of sportsmen resort as near to restricted areas as possible.

In the years to come considerable change of procedure is to be expected. One change which we now anticipate ourselves is the location of a salt water rearing pond with a fresh water supply available of sufficient volume to maintain a hatchery at the pond in order to eliminate the necessity of hatching in one place and transferring the fry to the ponds by laborious methods.

From marked specimens we hope to gather information relative to the effectiveness of the system and within the next year or two definite returns should begin to come in. To date we have positive information on two points. The growth of pinks and chums in brackish water is very rapid and the cost of rearing is less than in fresh water ponds.

# POLLUTION PROBLEMS IN THE STATE OF WASHINGTON AND THEIR SOLUTION

By H. W. Nightingale

*State Sanitary Engineer, State Department of Health.*

Investigations of the pollution of tidal waters and streams in the State of Washington are now being conducted by the State Department of Health in cooperation with the State Department of Fisheries. An act is appended relating to the preservation, protection and perpetuation of food fishes and shellfish, prohibiting the pollution of waters, defining the duties of certain state officers in connection therewith and amending Section 5734, Remingtons Compiled Statutes, as amended by Section 7, Chapter 90, Laws of 1923.

Under the present law, pollution problems are now in many instances, attacked from the broader conservation standpoint.

The quantities of raw sewage existing in tidal waters and in the numerous streams have thus far been insufficient to produce deleterious effects upon fish life. An increasing number of cities and towns have installed sewage disposal plants to reduce and purify their sewage in order to render it harmless from a health standpoint. It is an established fact that domestic sewage free from trade wastes is not especially harmful to fish life unless the dissolved oxygen content of the water is thereby diminished to about 30% of its normal saturation and the small plant and animal life living therein is altered in character.

The industrial development of Washington is now under way and as would be expected in a state well stocked with timber, pulp and paper mills are being established.

The pulp is produced by four distinct processes,—Sulfite, Sulfate, Lime Soda, and mechanical. Of the four, the sulfite process produces the most harmful effluent from a fisheries standpoint owing to its very high demand for oxygen dissolved in the water. Its effect upon sea water is very similar to that upon fresh. In this respect sulfite liquor is much more destructive than sewage. Wisconsin investigations indicate that on a five day oxygen demand basis, the wastes from a fifty ton sulfite mill are equivalent to the sewage of 81,300 people.

Aside from its high demand for oxygen, another and a partially indeterminate factor exists in connection with the concentration of sulfite liquor which might cause fish to avoid a stream for spawning purposes, the mouth of which

is polluted by this waste. It is probable that the smaller fish would be most susceptible under such conditions. No toxic action has yet been observed in experiments with this waste.

Since no economic method has yet been devised to recover the soluble constituents of sulfite liquor, dilution is the only method of disposal which is applicable to our conditions. Mechanical aeration and ponding have been used to a limited extent in Wisconsin as a means of reducing its oxygen demand.

The first large problem of sulfite liquor disposal arose last winter in connection with the establishment of a 100 ton pulp mill at Shelton. This mill is located on the shores of a bottle necked bay within two miles of valuable oyster grounds. The State Departments were assisted in this investigation by a sanitary engineer detailed from the U. S. Public Health Service.

An extensive float study of the tidal currents in the bay revealed the fact that a complete exchange of fresh seawater does not take place during the ebb and flow periods. Salinity determinations brought to light the fact that the fresh waters entering the bay maintain a definite equilibrium with the tidal waters.

In order to obtain as complete a picture as possible of the natural conditions existing in the bay and inlet before the mill started operations, dissolved oxygen determinations and surface plankton tows were made. A normal content of dissolved oxygen was found to be present at all tidal stages, ranging during the winter from 82% to 90% of saturation. Rich plankton tows of diatoms and Peridinieae were taken.

As a result of this investigation the Rainier Pulp & Paper Co. took action to prevent any possible damage to the oyster beds and installed a six mile pipe line to convey the waste liquor to a point in the inlet below the bay. A 100 horsepower centrifugal pump pumps the waste liquor against a 225 foot head into a six mile wood stave line of 12 inch diameter, thence into three 200,000 gallon wooden tanks. The discharge from these tanks takes place during ebb tide and is under hand control at present.

No observable effects have thus far been produced in the bay as far as oxygen depletion is concerned. The investigations of the conditions in the bay and inlet will be continued.

Several other problems pertaining to the disposal of sulfite liquor on fresh water streams and estuaries are now under consideration. One mill now under construction near Tacoma will install a pipe line and tank layout to cause the waste liquor to pass into a drainage creek thereby preventing the destruction of spawning grounds of the silver salmon in a nearby waterway and creek entering the waterway.

A sulfite mill to be located shortly on one of our rivers will present a considerable problem in connection with the run of Columbia river smelt. In this instance the city takes its water from the river for domestic use after filtration, thereby introducing another important factor.

In connection with the disposal of sulfite liquor, first hand information as to the specific character of the liquor as it is produced from our timber was determined by analyses. Samples of this liquor were obtained from mills now in operation in Washington and directly from the blow pits before dilution with wash water. The concentration was found to be similar to that produced in the Wisconsin mills. The 5 day oxygen demand ran as high as 20 to 25 thousand parts per million. Dilutions of the liquor were made both with seawater and fresh and incubated in sealed glass bottles to determine the initial, 1 day and 5 day oxygen demand. The results of these analyses are embodied in a special report.

Since the sulfite mills are in most instances provided with modern savealls there is little pollution from waste fibres.

No mills utilizing the sulfate process have yet been under consideration. Since most of the chemicals must be recovered it is not likely that serious pollution will result except on very small streams. Ponding has been successfully employed in other sections of the country to dispose of this waste.

A mill producing pulp from waste wood and magazines by the lime soda process along the shores of a small creek is now under investigation. A fish hatchery is located on the upper reaches of this creek and it is customary to release the fry in the creek after rearing.

The creek water is under tidal influence near its mouth. The waste has a caustic alkalinity at times and contains small quantities of alum and dyes resulting from the manufacture of newspaper stock carried on in conjunction with the pulp making. A considerable quantity of waste fibers

are allowed to discharge into the creek at all stages of the tide. No savealls have yet been installed at the mill.

Experiments were performed by exposing the fry of silver salmon in screened floating boxes in the creek at low tide. Control tests were simultaneously made in the creek above the mill. Mortality was high among the fry located near the mill but not above in the fresh waters outside the influence of the pollution. Death occurred in 3 to 4 hours in the waters near the mill.

Savealls will shortly be installed at the mill and waste free caustic will be eliminated as far as possible. By mixing fresh water from another source with the effluent before discharge it may be possible to increase the dissolved oxygen content to a point near normality. If the result of these improvements in operation at the mill proves to be successful, fish may be released in the creek next season. If not, the plan of piping the waste out of the creek will be considered. The solid wastes from the lime soda process as practiced at this mill are piled up near the banks of the creek. These solids are largely black ash and lime sludge. No evidences of pollution from these sources have yet been observed. Both are largely insoluble. Although harmless in this instance the writer has observed the destruction of seed clams at the mouths of certain rivers in the State of Maine as the result of an accumulation of black ash on the flats.

There is only one soda lime pulp mill in the state at the present time.

Observations of the wastes discharged from a mechanical pulp mill located near Seattle indicate that with sufficient tidal movements there is small chance for harmful pollution. No chemicals are used in this process in which the wood is ground in large grindstones. Savealls prevent the loss of all but an insignificant quantity of fibers.

There are several other types of manufacturing plants whose wastes will be investigated as the occasion demands. Beet sugar, yeast, cheeses and other dairy products are produced. Thus far none of the strictly toxic wastes have been encountered, except the occasional and accidental discharge of cyanide tailings from mines in British Columbia which enter the Similkameen and Okanogan rivers during the months of early spring.

One feature of our present law facilitates the investigational work. Quoted in part it is as follows: "Before any industrial or manufacturing concern the construction and

operation of whose plant will necessitate the dumping of refuse or waste materials, substances or matters into any waters of this state either fresh or salt, shall proceed with construction and operation, it shall submit for the approval of the Director of Fisheries and Game, through the Supervisor of Fisheries, and the Director of Health, detailed plans for the disposal of its refuse or waste materials substances or matters, and if such plans do not in the judgment of the Supervisor of Fisheries and Director of Health make adequate provision for safeguarding fish and shellfish in such waters, the said Supervisor of Fisheries and Director of Health shall disapprove the same and it shall be unlawful for the person, firm or corporation to proceed with the operation of its said plant until the plans are revised in such a manner as to meet the objections of the Supervisor of Fisheries and Director of Health."

By means of this ruling it is possible to check pollution and to become familiarized with new problems as they arise. In many cases sites would not be chosen if it was apparent that the wastes could not be economically taken care of.

The attitude of industrial plant owners has so far been commendable and we have every reason to expect that dangerous pollution can be kept from our streams and shellfish grounds in the future. Since our streams and tidal waters are not yet grossly contaminated it appears that stream pollution activities in this state have begun at a fortunate time.

**State of Washington**

**Dept. of Fisheries & Game, Division of Fisheries**

**414 Bell St. Terminal,**

**Seattle, Washington.**

**SESSION LAWS OF THE STATE OF WASHINGTON**

**Regular Session—1927**

**Chapter 299 (H. B. 282.)**

**FOOD AND SHELL FISH—POLLUTION OF WATERS.**

An act relating to the preservation, protection and perpetuation of food fishes and shellfish, prohibiting the pollution of waters, defining the duties of certain state officers in connection therewith and amending Section 5734, Remington's Compiled Statutes, as amended by Section 7, Chapter 90, Laws of 1923.

Be it enacted by the Legislature of the State of Washington:

Section 1. That section 5734 of Remington's Compiled Statutes, as amended by section 7, Chapter 90, Laws of 1923, be amended to read as follows:

Section 5734. It shall be unlawful to cast or pass, to suffer or permit to be cast or passed into any waters of this state, either fresh or salt, any sawdust, planer shavings, wood pulp or other waste, lime, gas, oil, oil products, grease, coculus indicus, or any chemical substance, except coal mine waste or drainage, in quantities sufficient in the judgment of the state fisheries board and the state board of health to injuriously affect, destroy or diminish the growth of the plankton, benthos or algae or the fish and shellfish inhabiting such waters or impair the supply thereof. It shall also be unlawful to cast or pass, to suffer or permit to be cast or passed into any waters of this state, either fresh or salt, any refuse or waste material, substance or matter at any time whatsoever which may be determined by the state board of fisheries to be deleterious to fish or shellfish. The state board of health shall cooperate with the state fisheries board in the making of its said determination. The state fisheries board shall have the right to call upon the department of health for such investigation and report as may be necessary from time to time concerning the effect upon aquatic life of various kinds of refuse and waste materials, substances or matters to the end that it may from time to time, as warranted by conditions, promulgate rules and regulations prohibiting the deposit in the waters of the state, either fresh or salt, of such refuse or waste materials, substances or matters as may be deleterious in their effect upon fish and shellfish. The rules and regulations shall be promulgated and published in the manner now or hereafter prescribed for the promulgation and publication of its rules and regulations relating to the taking of food fish and they shall constitute prima facie evidence that the refuse or waste materials, substances, or materials therein declared to be deleterious are in fact deleterious to fish and shellfish inhabiting the waters. In any action or proceeding involving the validity or construction of any

such rule or regulation it shall be competent to plead the same by title and number and to prove the same by the introduction of a true and correct copy thereof, duly certified by the secretary of the state fisheries board. The director of fisheries and game, through the supervisor of fisheries, with the approval of the state fisheries board, shall have the power to grant permits for the sawing of logs in such waters as in his judgment can be used for that purpose without injury to fish and shellfish. Before any industrial or manufacturing concern the construction and operation of whose plant will necessitate the dumping of refuse or waste materials, substances or matters into any waters of this state, either fresh or salt, shall proceed with construction and operation, it shall submit for the approval of the director of fisheries and game, through the supervisor of fisheries, and the director of health, detailed plans for the disposal of its refuse or waste materials, substances or matters, and if such plans do not in the judgment of the supervisor of fisheries and director of health make adequate and effective provision for safeguarding fish and shellfish in such waters, the said supervisor of fisheries and director of health shall disapprove the same and it shall be unlawful for the person, firm or corporation to proceed with the operation of its said plant until the plans are revised in such manner as to meet the objections of the supervisor of fisheries and director of health. Any person, firm or corporation feeling himself or itself aggrieved by any order or ruling of the supervisor of fisheries and the director of health disapproving the detailed plans for disposal of refuse or waste materials, substances or matters submitted by an industrial or manufacturing concern as above provided, shall have the right of appeal from such order or ruling to the superior court of the county in which the plant of such industrial or manufacturing concern is situated, in the manner provided by law for taking appeals from justices courts, and upon such appeal being taken and perfected, the same shall be set for hearing and heard by the judge of said court, de novo without a jury and at the conclusion of the hearing the judge shall enter an order approving the plans submitted, or modifying and approving such plans, or disapproving the same, as may to the judge seem necessary for the protection of the public health and the fish and shellfish inhabiting the waters of this state.

Passed the House February 24, 1927.
Passed the Senate March 8, 1927.
Approved by the Governor March 19, 1927.

(NOTE: All laws passed by the legislature, unless otherwise specified, become effective 90 days after the close of the legislative session.)

# APPENDIX

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# American Fisheries Society

**Organized 1870**

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CERTIFICATE OF INCORPORATION

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We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

| | |
|---|---|
| SEYMOUR BOWER | (Seal) |
| THEODORE GILL | (Seal) |
| WILLIAM E. MEEHAN | (Seal) |
| THEODORE S. PALMER | (Seal) |
| BERTRAND H. ROBERTS | (Seal) |
| HUGH M. SMITH | (Seal) |
| RICHARD SYLVESTER | (Seal) |

Recorded April 16, 1911.

# CONSTITUTION AND BY-LAWS.

(As amended to date)

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## ARTICLE I

### Name and Object

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

## ARTICLE II

### Membership

*Active Members.*—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society.

The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. In case of non-payment of dues for two consecutive years, notice shall be given by the Treasurer in writing, and such member remaining delinquent after one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues shall be ineligible for election as a new member for a period of two years, except upon payment of arrears.

*Club Members.*—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

*Libraries.*—Libraries shall be admitted to membership upon application and the payment of one year's dues. The annual dues for libraries shall be three ($3.00) per year.

*State Memberships.*—Any State, Provincial of Federal Department of the United States, Canada or Mexico may, upon application and the pay-

ment of one year's dues become a state member of this Society. The Annual dues for State Memberships shall be ten ($10.00) dollars per year.

*Life Memberships.*—Any person may, upon a two-thirds vote of the members present at any regular annual meeting and the payment of fifty ($50.00) dollars become a life member of this Society and shall thereafter be exempt from payment of annual dues. The President, Secretary and Treasurer of the Society are hereby authorized to transfer members from the active list to the list of life members at their discretion for good and sufficient reason, such as inability to pay dues, provided that no member shall be so transferred unless he shall have paid dues as an active member of the Society for at least twenty-five years.

*Patrons.*—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron of this Society with all the privileges of a life member, and shall be listed in all the published membership lists of the Society.

*Honorary and Corresponding Members.*—Any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President (by name) of the United States, the Governors (by name) of the several states and the Secretary of Commerce of the United States (by name) shall be honorary members of the Society.

*Election of Members Between Annual Meetings.*—The President, Secretary and Treasurer of the Society are hereby authorized during the time intervening between annual meetings, to receive and act upon all applications for individual and club memberships. A majority of such committee shall decide upon the acceptance of such applications.

*Voting.*—Active members and life members only shall have the right to vote at regular or special meetings of the Society. Fifteen voting members shall constitute a quorum for the transaction of business.

## ARTICLE III

### Funds

*Current Fund.*—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

*Permanent Fund.*—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

## ARTICLE IV

### Officers

The officers of this Society shall be a President and a Vice-president, who shall be ineligible for election to the same office until a year after the expiration of their term; a Secretary, a Treasurer, a Librarian, and an Executive Committee of seven, which, with the officers before named, shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five Vice-presidents who shall be in charge of the following five divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

*Duties of Officers.*—The President shall preside at the annual and all special meetings of the Society, shall be ex-officio chairman of the Council of the Society, and shall exercise general supervision over the affairs of the Society.

The Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, attend to the publication and distribution of its Transactions, attend to its correspondence, promote its membership, and arrange for annual and special meetings.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of one thousand ($1,000.00) dollars to be approved by the Executive Committee and to be paid for by the Society.

The Librarian shall have the custody of the library of the Society, in-

cluding its permanent records and printed Transactions and shall have charge of the sale of surplus copies of such Transactions. Other officers shall perform such duties as shall be assigned them by the President.

## ARTICLE V

### Meetings

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the Executive Committee.

## ARTICLE VI

### Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Applications for memberships.
4. Reports of officers.
   a. President.
   b. Secretary.
   c. Treasurer.
   d. Vice-Presidents of Divisions.
   e. Standing Committees.
5. Committees appointed by the President.
   a. Committee of five on nomination of officers for ensuing year.
   b. Committee of three on time and place of next meeting.
   c. Auditing committee of three.
   d. Committee of three on program.
   e. Committee of three on publication.
   f. Committee of three on publicity.
6. Reading of papers and discussions of same.
   (*Note*—In the reading of papers preference shall be given to the members present).
7. Miscellaneous business.
8. Adjournment.

## ARTICLE VII

### Changing the Constitution

The Constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.

# American Fisheries Society

## LIST OF MEMBERS, 1927-1928.

### (Showing Year of Election to Membership)

### HONORARY MEMBERS

The President of the United States
The Secretary of Commerce of the United States.
The Governors of the several States.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas American Museum of Natural History, New York, N. Y.
'12 Calderwood, W. L., Inspector of Salmon Fisheries for Scotland, Edinburgh, Scotland.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'88 Lake St. Clair Shooting and Fishing Club, Detroit, Mich.
'17 Mercier, Honore, Minister of Colonization, Mines and Fisheries, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'95 New York Association for the Protection of Fish and Game, New York City.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.
06 Perrier, Prof. Edmond, Director Museum of Natural History, Paris, France.
92 Vinciguerra, Prof. Dr. Decio, Director Royal Fish Culture Station, Rome, Italy.

### CORRESPONDING MEMBERS

'84 Apostolides, Prof. Nicoly Chr., Athens, Greece.
'87 Armistead, J. J., Dumfries, Scotland.
'04 Ayson, L. F., Commissioner of Fisheries, Wellington, New Zealand.
'22 Director, All-Russian Agricultural Museum, Fontanka 10, Leningrad, Russia.
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